Appendix B. Watershed Model Documentation

Final:
The Lower Platte Missouri Tributaries
Northern and Central Model:
Regionalized Soil Water Balance Model

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1. Introduction

1.1. Authorization

The Flatwater Group, Inc. (TFG) has prepared this report as authorized under Task Order 4 Contract 802 between the Nebraska Department of Natural Resources (DNR) and TFG originally dated December 17, 2014 and continued under DNR contract 984 dated 5/26/2017.

1.2. Purpose and Scope

DNR, in conjunction with their contractor HDR and its subcontractors, is developing the Lower Platte Missouri Tributaries Model (LPMT) for use in evaluating water planning and integrated water resources management efforts within eastern Nebraska. The project consists of a groundwater flow model and a watershed model. Through this project, results of the two models are integrated to identify actions likely to achieve the project goals.

This report focuses on the processes and application of the watershed model. It discusses the development, general methodologies, and how this model was applied across the project domain. Select summaries of the water balance, including pumping from groundwater and recharge depths are included in the results section. Finally, the appendix contains the necessary information to allow a new user to setup and run the watershed model; including a detailed description of the programs which constitute this model.

The primary role of the watershed model is to ensure that the water supplies and uses were accounted for within a balanced water budget. The water budget is comprised of precipitation (P), applied irrigation water (I), evapotranspiration (ET), deep percolation (DP), runoff (RO), and changes in soil water content (ΔSWC).

1.3. Acknowledgements

A number of individuals from several different entities supported the development of the LPMT Model. This section is intended to recognize these individuals:

Project Manager – Mahesh Pun (DNR)
Project Manager – John Engel (HDR)

<u>Groundwater Model Development (HDR)</u>
Larry Land – Project Leader
Tiraz Birdie (Tiraz Birdie Consulting)
Taylor Weise
Nathan Rossman – Project Leader
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Watershed Model (TFG)
Marc Groff – Project Leader
Amy Fosler

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Philip Paitz – Project Leader
Jennifer Schellpeper
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Amy Zoller
Tim Freed
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Hua Gua

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While not a formal member of the LPMT modeling team, it is appropriate to recognize the efforts of Dr. Derrel Martin (University of Nebraska-Lincoln) for his guidance and assistance in developing the procedures described in this report. Dr. Martin developed the CROPSIM model which provides the results upon which the Regionalized Soil Water Balance model relies.

Additionally, the efforts of Luca DeAngelis (formerly of HDR), Ruopu Li (formerly of DNR), and Micheal Ou (formerly of DNR) in the conceptualization and initialization of the project deserve to be acknowledged.

2. Study Area

The LPMT model domain consists of approximately 10.31 million acres (16,100 mi^2) in the eastern portion of Nebraska. The Missouri River comprises the northern and eastern borders of the model which extends westward to the middle of Knox and Merrick counties. The Blue River is used as a border in the southwest. Finally, the model approaches the southern border of Nemaha and Johnson counties in the south. The model domain encompasses the eastern portion of the Platte, Loup, and Elkhorn Rivers, as well as the direct tributaries to Missouri River.

3. Conceptual Model

The hydrologic cycle as modified by irrigation and other human activity serves as the conceptual model for this project. Figure 1 is a schematic illustration of the hydrologic cycle for a system where the use of water for irrigation is important. This figure provides visual context for discussion of how the system is modeled.

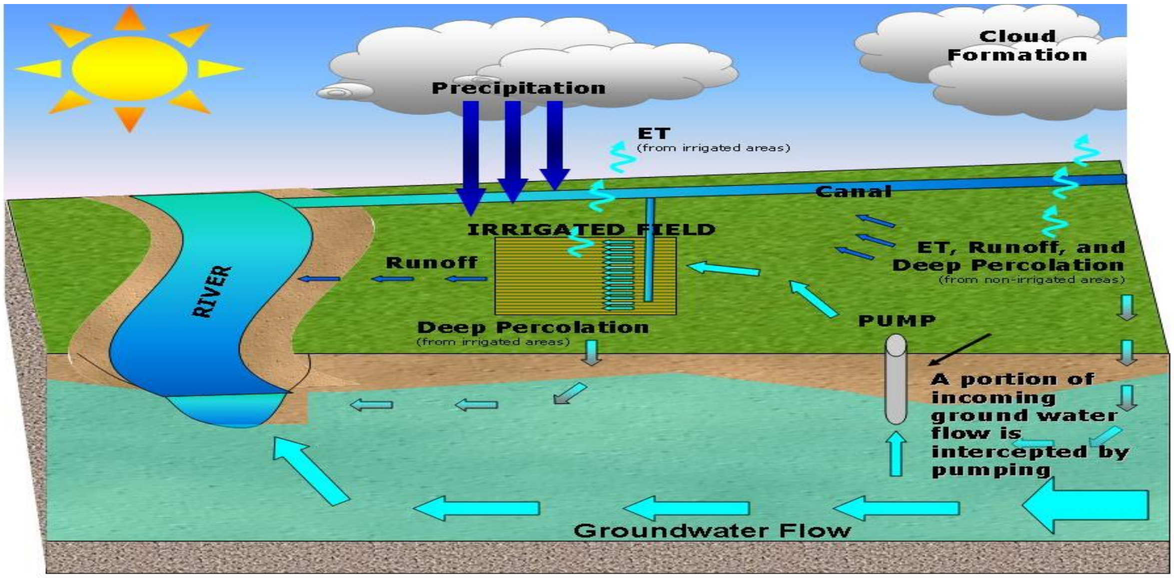

Figure 1. Illustration of hydrologic cycle in which irrigation is important.

The intended use of the model drives what physical characteristics of the study are important to properly represent. In the case of the Regionalized Soil Water Balance (RSWB) model, information about the area's climate, soils, land use, and farming practices are important characteristics to address when attempting to estimate the amount of water needed to irrigate crops, to develop estimates of the amount of groundwater recharge resulting from deep percolation, and to develop estimates of runoff contributions to total stream flow.

In general, Nebraska has a continental climate exhibiting large temperature variations season to season as well as year to year. In order to account for the highly variable climate in the study area, the RSWB model incorporated a reference crop based methodology. The reference crop (tall crop; alfalfa) was used to represent the evaporative demand of the climate, and in this process, provide a method to standardize crop water use to climatic conditions.

Soils in the study area include eolian sands, alluvium, loess, and glacial till. The study area is dominated by rolling hills with major valley along major rivers and creeks with the western edge of the model domain merging into the sandhills. Land use is often directly tied to soil type. Both the sandhills and steeper upland areas are well suited to be used as rangeland. The more gently sloping soil and deeper loamy soils are well suited to crop production. To account for this variability, the RSWB model used an approach sensitive to key soil properties (water holding capacity, hydrologic soil group) and made use of annually updated land use files which reflected the area’s development.

As land use has changed over the course of time in this area, so to have the related production practices. As technology has advanced, both the types of crops and the methods by which given crops are produced have evolved. Of particular importance to this study are the changes which have occurred related to irrigation. The use of groundwater as compared to surface water as a source for irrigation has increased. The methods by which irrigation water is applied to crops has changed and become generally more efficient in terms of the amount of water applied compared to the amount of water consumed by crops. The methods employed by the RSWB model attempted to capture the major effects of these changes by trending CROPSIM results developed using different production practice inputs and additionally by trending irrigation application efficiencies over time.

4. Watershed Model

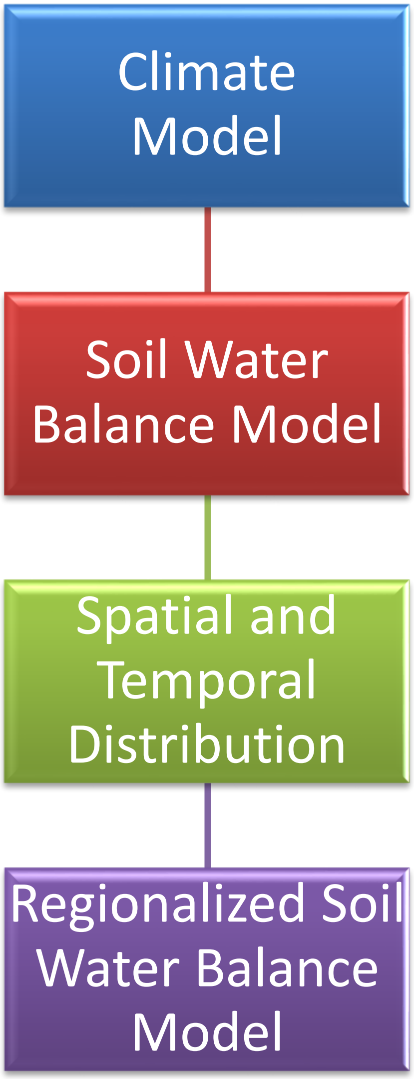

Figure 2. Components of the Watershed model

The Regionalized Soil Water Balance model represents one part of what is more broadly referred to as the watershed model. The primary purpose of the watershed model is to ensure that the water supplies and uses are accurately accounted for within a balanced water budget. For this purpose, the water budget is represented by precipitation (P), applied irrigation (I), evapotranspiration (ET), deep percolation (DP), runoff (RO), and change in soil water content (ΔSWC). The watershed model can be divided into four parts; a climate model, a soil water balance model, spatial and temporal distribution routines, and the Regionalized Soil Water Balance (RSWB) model (Figure 2).

4.1. The Climate Model

Weather is the primary input into the Watershed model, while the remaining parts of the model reflect how the system reacts to the weather conditions. Precipitation, temperature, and reference ET are the necessary weather data inputs to the soil water balance model discussed in further detail below. Precipitation and temperature are readily available from weather stations; however, reference ET must be calculated. There are multiple ways to calculate the Reference ET depending on the breadth of information available. The watershed model uses two approaches: the ASCE standardized Penman-Montieth [1], and a modified Hargreaves-Samani [2]. The Penman-Montieth approach is considered to be more accurate, however, the method requires several meteorological readings (wind speed, relative humidity, and net radiation) to calculate reference ET. Hargreaves-Samani, on the other hand, only requires the temperature measurements to estimate reference ET; however, the simplicity of this approach is evident in its results.

Up until the last couple of decades, the extended data set needed for the Penman-Montieth method was not readily collected. The dataset is limited both by the timeframe and the number of stations collecting this information. Within Nebraska, climate stations which collect the needed information for a Penman-Montieth based reference ET calculation are part of the Automated Weather Data Network (AWDN) and are maintained by the High Plains Regional Climate Center. As the temporal domain defining LPMT modeling efforts extends more than half a century in the past, using the Penman-

Montieth approach alone was unfeasible. Rather a calibrated Hargreaves-Samani approach was employed. Using available AWDN records, reference ET values using the Penman-Monteith method were computed and compared to the reference ET values computed using the Hargreaves-Samani methodology. A relationship was developed between the two estimates and the geographical location of the weather station to develop geographically linked coefficients for the Hargreaves-Samani method which could be applied for the entire period of record. This allows the use of the National Weather Service and Cooperative (NWS/Coop) network of weather stations. These stations usually collect less data but have been collecting the data for a longer period. Furthermore, this network of stations is relatively denser, refining the scale of influence any individual station exhibits. A more detailed description of this process can be found in the document entitled *CROPSIM Net Irrigation Requirement* [3].

4.2. Soil Water Balance Model

The Soil Water Balance Model used by the watershed model is called CROPSIM. CROPSIM is a water driven point source model which uses weather data in combination with representative system characteristics (crop phenology, soils, management, and irrigation) to estimate the daily soil water balance [4]. It was developed by Dr. Derrel Martin with the University of Nebraska-Lincoln's Department of Biological Systems Engineering to aid in the estimation of ET, DP, and runoff which occurs on a range of cropped and naturally vegetated systems in primarily agricultural regions. This report provides a short overview of the mechanics of the CROPSIM model, further information can be found in the CROPSIM documentation [5].

CROPSIM begins with a known amount of water in the soil profile (SWC_{i-1}). Precipitation (P) from the weather data is applied. The portion of the precipitation which infiltrates into the soil is determined with the remainder going to runoff (RO). This is accomplished using a modified curve number approach with considerations for soil moisture content and surface residue. The infiltrated precipitation is used to fill the top soil layer, and then continues to fill each subsequent layer until the infiltrated precipitation is assigned. If there is more infiltrating water than there is room in the soil profile, this water will drain out the bottom of the soil profile as deep percolation (DP).

The amount of water in the soil is calculated. For irrigated simulations[1], if the soil water content drops below a management specified level of depletion this triggers an irrigation event[2]. A gross amount of water is applied with a net amount of irrigation infiltrating into the soil profile. The net irrigation fills the top layers and continues to fill subsequent layers until the entire depth of net irrigation water is assigned.

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[1] CropSim is capable of simulating several different types of irrigation. For the watershed model simulations irrigation volumes are based upon the level of depletion in the soils and sprinkler irrigation. Other techniques include fixed dates, precipitation forecasting, and precipitation and evapotranspiration forecasting.

[2] Under the simulation technique used, it is assumed that the producer will only irrigate when there is sufficient space in the soil profile to hold the depth of net irrigation.

Vegetative growth is simulated from the specified planting date; progressing through the phenologic development tracked by growing degree days. The development of the plant extends the root system deeper into the soils allowing for greater access to soil moisture. At the same time the development of the canopy expands the transpiration potential of the crop. Transpiration demands are determined using Basal crop coefficients. Next it is determined if there is sufficient water in the root zone. If there is sufficient water to meet the transpiration demands, the water is transpired; otherwise, the crop is stressed and a reduced rate of transpiration is determined. Evaporation from the soil surface is also determined. The combination of the transpired and evaporated water is removed from the root zone through evapotranspiration (ET).

Finally, the amount and distribution of water in the soil profile is determined. If there is water in a soil layer in excess of field capacity, the water is moved to the ensuing layers. If there is no room in the profile below the water will drain as deep percolation (DP). These steps are used to calculate the ending soil water content (SWC_i) as shown by Equation 1.

$$SWC_i = SWC_{i-1} + P + I_{net} - RO - ET - DP \tag{1}$$

The daily calculations are compiled and written to monthly summaries.

Long term simulations were made subjecting a variety of vegetation types to the climatic conditions measured at selected weather stations. This process is repeated for a selection of crops (5), soils (22), and irrigation methods (irrigated and non-irrigated) at each weather station. Furthermore, to capture the changing effect of improved technology and farming practices, three sets of CROPSIM runs were created. These runs represent the tillage practices common in 1949, 1973, and 1998 respectively.

4.3. Spatial and Temporal Distribution Model

The next portion of the watershed model is to interpolate between the points where CROPSIM was modeled from both a spatial and temporal standpoint. First the CROPSIM results were time trended between each of the three tillage scenarios. This was accomplished using linear interpolation.

The second step was to spatially interpolate the time trended results to the geographic extents of the watershed model domain. The watershed model uses the groundwater model grid and selection of weather stations dispersed throughout and surrounding the grid. First, for each cell the three nearest weather stations and their distance to the cell centroid was established. Next each cell within the grid was assigned a CROPSIM soil class based upon the local dominant soil type. Finally, the water balance parameters are interpolated between the three nearest weather stations using an inverse weighted distance technique and the assigned soil class. The results are a set of files depicting the water balance parameters (P, NIR, DP, RO, and ET) for each combination of crop and irrigation method (dry or irrigated).

4.4. Regionalized Soil Water Balance Model (RSWB)

The primary purpose of the RSWB is to develop estimates of pumping and recharge and create the appropriate .WEL and .RCH files for inclusion in the groundwater model. To accomplish this, the RSWB determines precipitation, estimates irrigation demand, applies irrigation, and partitions the applied water while adjusting for non-idealized conditions. Additionally, the RSWB is used to further partition field runoff between stream flow contribution, recharge, and ET. Furthermore, the RSWB is capable of incorporating miscellaneous sources of recharge and pumping into the .WEL and .RCH deemed significant but not readily determined within the construct of the RSWB model.

The remainder of this publication will describe the processes, inputs, and results of the RSWB model.

5. RSWB Model Construction

The RSWB consists of eight programs (listed below), which incorporate distributed CROPSIM results, develop irrigation estimates, make adjustments to the water balance parameters, organize the results into properly formatted groundwater model input files, and generate water balance summary reports. The programs relate to one another as show in Figure 3.

1. Irrigation Application and Demand (IAD)
2. Water Supply Partitioning Program (WSPP)
3. Make Well
4. Make Recharge
5. Compile Well
6. Compile Recharge
7. WSPP Report
8. Compile WSPP Report

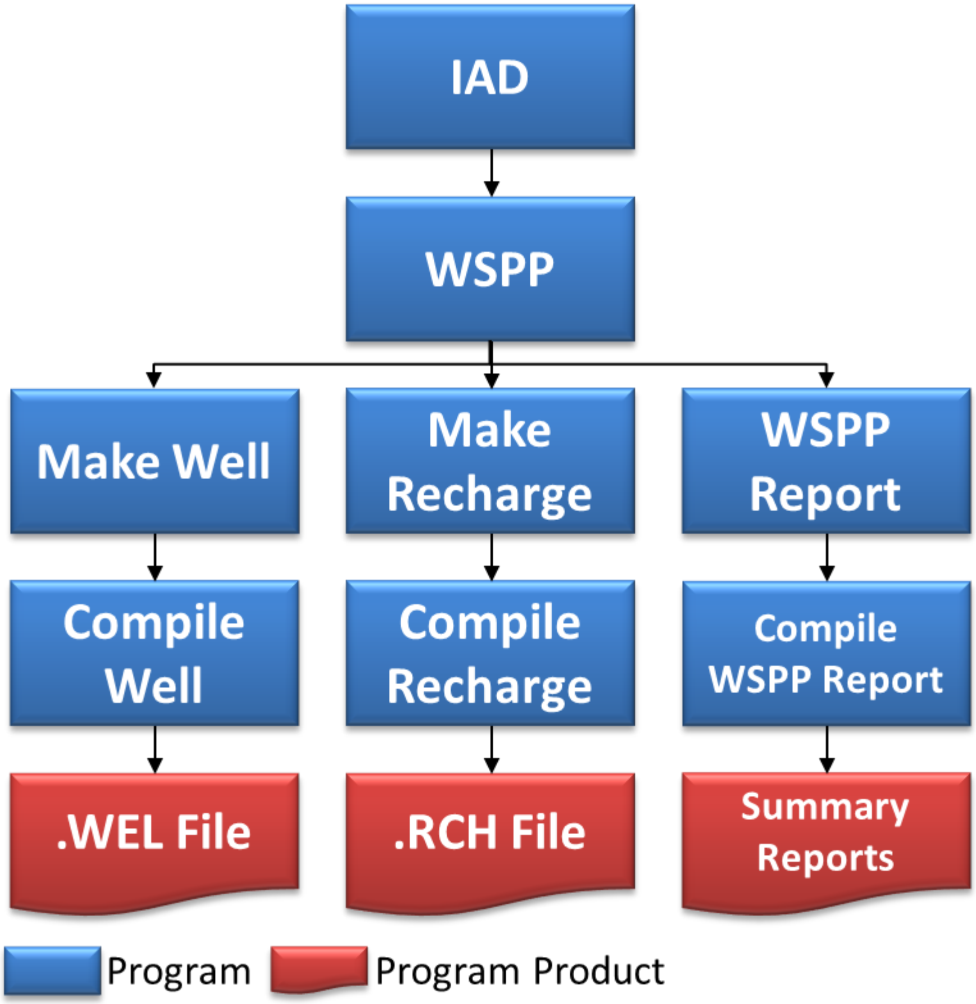

Figure 3. The LPMT RSWB Model programs and output.

The following is a general description of each program. Generalized schematics showing major conceptual components of the major programs are provided to assist a user interested in reviewing source code. The descriptions discuss in general terms the inputs required for each program. Refer to Appendix B Model User's Setup Guide for a more complete discussion of the input parameters and their development.

5.1. Irrigation Application and Demand (IAD)

The irrigation application and demand program develops estimates of applied irrigation volumes based upon land use classifications and system type. The IAD uses the NIR and application efficiency (AE) to estimate the gross volume of irrigation water delivered to each cell, as well as the depth of irrigation water that was applied to each crop. The volume and depths of water that are applied are passed to the next set of programs as illustrated in Figure 4.

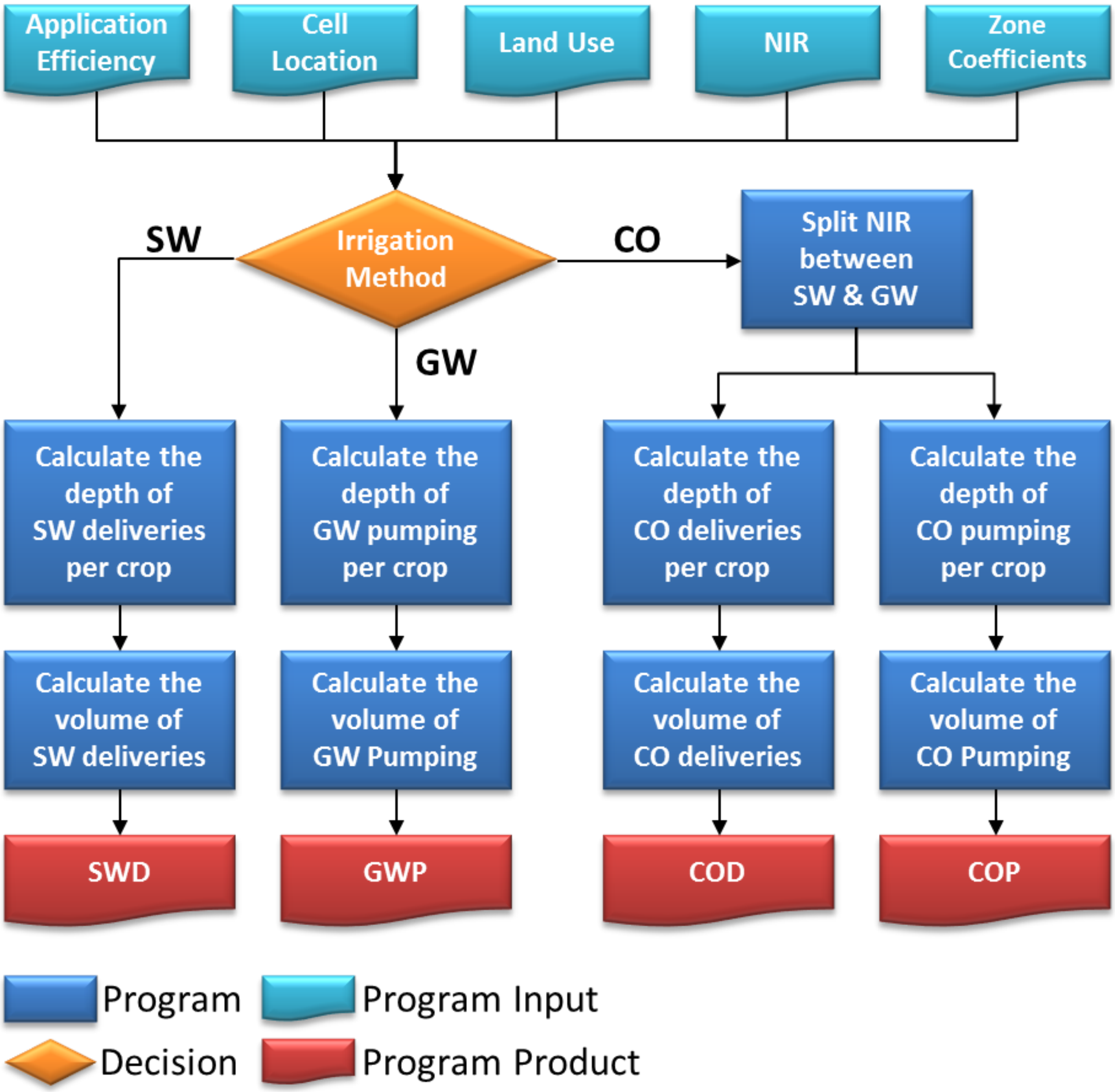

Figure 4. Flow chart depicting the inputs, outputs, and major functions of the IAD program.

The volume of irrigation is estimated using the NIR from CROPSIM, adjusting it with the NIR target, and then determining the gross irrigation volume needed using the application efficiency (Equation 2).

$$Irr_{crop,irr\ type} = NIR_{crop} * \frac{Target_{NIR}}{AE_{irr\ type}} \tag{2}$$

$Irr_{crop,\ irr\ type}$	Depth of irrigation water applied to the crop from an irrigation source
NIR_{crop}	Net irrigation requirement for a given crop
$Target_{NIR}$	Target indicating the portion of the full demand to be applied
$AE_{irr\ type}$	Application efficiency of the irrigation source
crop	Land use classification
irr type	Source of water; groundwater or surface water

The volume of water applied within a cell is computed by multiplying the per acre value by the acres covered by the crop. This is repeated for each crop being grown in the cell (Equation 3).

$$Irr_{cell,irr\ type} = \sum\left(Irr_{crop,irr\ type} * Acs_{crop,irr\ type}\right) \tag{3}$$

$Irr_{cell,\ irr\ type}$	Volume of irrigation water applied to the cell from irrigation source
$Acs_{crop,\ irr\ type}$	number of acres being grown of the crop type and from the irrigation source

For land irrigated with both surface water and groundwater, the NIR value used in Equation 2 was weighted by use of a co-mingled partitioning factor (CM_{split}). The factor is used to determine the portion of the NIR which was met by either groundwater pumping or surface water deliveries (Equations 4-5)

$$NIR_{SW} = NIR * CM_{split} \tag{4}$$

$$NIR_{GW} = NIR * \left(1 - CM_{split}\right) \tag{5}$$

NIR	Net irrigation requirement
NIR_{SW}	NIR met by surface water deliveries
NIR_{GW}	NIR met by groundwater pumping
CM_{split}	Factor used to split NIR between groundwater and surface water
SW	Surface water source of irrigation
GW	Groundwater source of irrigation

The NIR parameter in Equation 2 was then replaced with NIR_{SW} and NIR_{GW} for calculations of applied surface water or pumped groundwater, respectively.

5.2. Water Supply Partitioning Program (WSPP)

The purpose of WSPP is to partition precipitation and applied irrigation between evapotranspiration, recharge, runoff and change in soil water content. Additionally, WSPP is used to adjust the parameters of the water balance from the idealized conditions in CROPSIM, through calibration, to more accurately reflect the conditions experienced in the field. This is accomplished using the distributed water balance parameters, land use classification, and applied irrigation volumes (Figure 5). WSPP is capable of incorporating either the estimated irrigation amounts developed in the IAD or an irrigation data set developed outside the model (e.g. metered well pumping records)[3].

All adjustments made to any water balance parameter must maintain the water balance shown in Equation 6. Precipitation and change in soil water content were kept constant throughout the process.

$$P + NIR - ET - DP - RO = \Delta SWC \tag{6}$$

P	Precipitation
ET	Evapotranspiration
DP	Deep percolation
RO	Runoff
ΔSWC	Change in soil water content

Each crop type can be supplied by each irrigation source separately. Calculations are first made for rainfed conditions. An adjustment is made to the dryland ET to reflect the difference between the idealized conditions from CROPSIM and those observed in the field (Equation 7).

$$ET_{dry,adj} = ET * ADJ_{ET,dry} \tag{7}$$

ET	Evapotranspiration
$ET_{dry,\ adj}$	Adjusted dryland ET
$ADJ_{ET,\ dry}$	Dryland ET adjustment factor

The change in ET was converted to runoff and deep percolation (Equation 8-10).

$$\Delta ET_{dry} = ET - ET_{dry,adj} \tag{8}$$

$$RO_2 = \Delta ET_{dry} * DryET2RO \tag{9}$$

$$DP_2 = \Delta ET_{dry} - RO_2 \tag{10}$$

ET	Evapotranspiration
$ET_{dry,\ adj}$	Adjusted dryland ET

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[3] For the LPMT modeling, the irrigation estimates from the IAD were used.

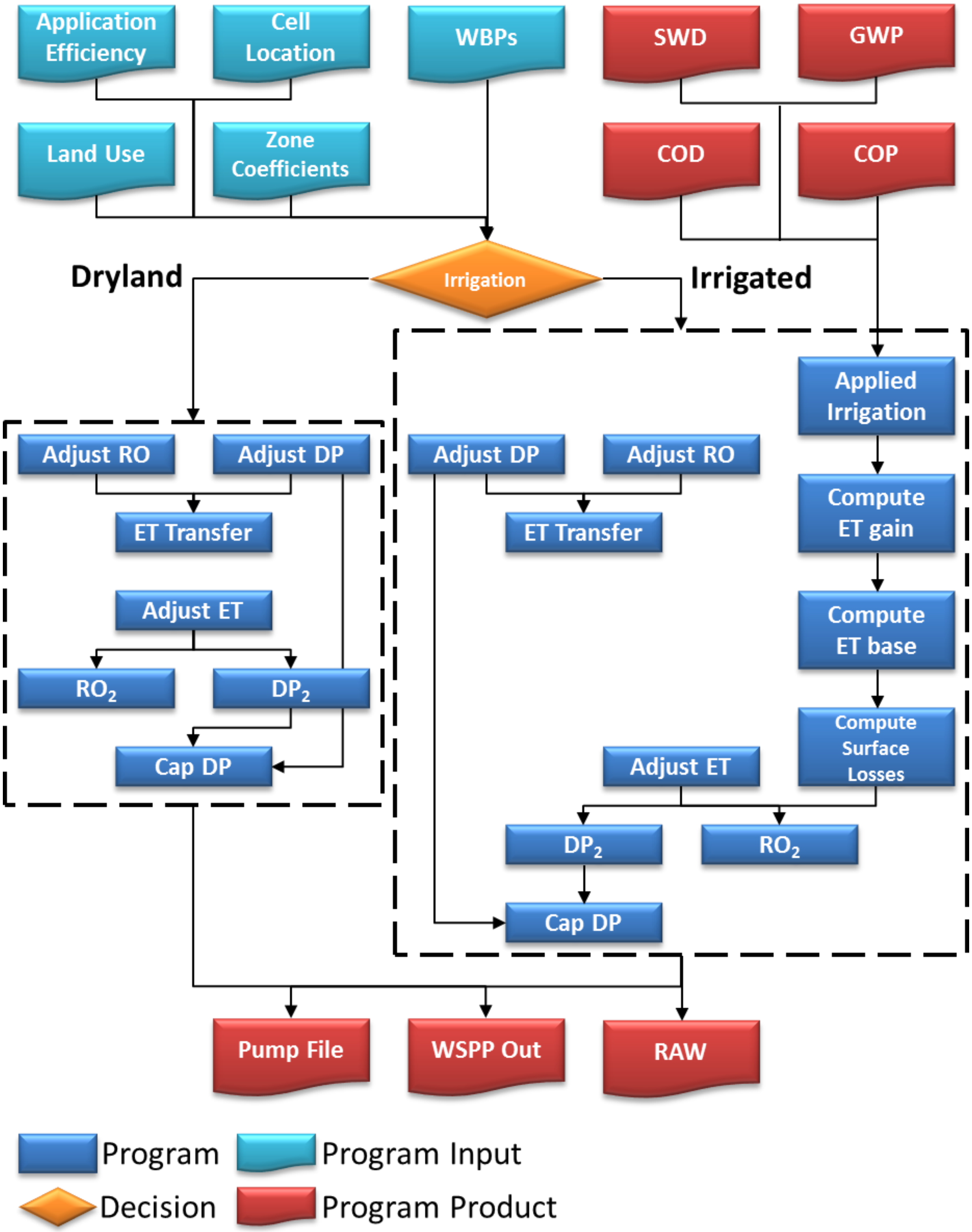

Figure 5. Flow chart depicting the inputs, outputs, and major functions of the WSPP program.

ΔET_{dry}	Change in dryland evapotranspiration; unassigned water
RO_2	Additional runoff from the application of irrigation and movement to non-idealized conditions
DP_2	Additional recharge from the application of irrigation and movement to non-idealized conditions
DryET2RO	Partitioning factor used to divide unassigned water between runoff and deep percolation
dry	Not irrigated
adj	Adjusted

Likewise, runoff and deep percolation adjustment factors are available to make adjustments to the volume of either respective parameters coming out of CROPSIM. Changes in these parameters were converted to non-beneficial consumptive use (ET) (Equations 11-13).

$$RO_1 = RO * ADJ_{RO} \tag{11}$$

$$DP_1 = DP * ADJ_{DP} \tag{12}$$

$$ET_{trans} = (DP - DP_1) + (RO - RO_1) \tag{13}$$

RO	Runoff
DP	Deep percolation
RO_1	Adjusted runoff
DP_1	Adjusted deep percolation
ADJ_{RO}	Runoff adjustment factor
ADJ_{DP}	Deep percolation adjustment factor
ET_{trans}	Runoff and deep percolation from CROPSIM converted into non-beneficial ET

Finally, the WSPP program allows for upper limits to be applied to recharge rates. A diminishing returns function is employed such that after the annual rate of deep percolation exceed a lower threshold; as the depth of deep percolation goes to infinity, the depth realized by the model approaches the deep percolation cap (Equations 14-17). This routine was implemented to account for the fact that soils may be limited on their ability to drain water which has seeped below the modeled root zone, causing over estimation of recharge rates.

$$\lim_{DP_1+DP_2\to\infty} DP_{dry,tot} = DP_{cap} \tag{14}$$

$$DP_{dry,tot} = DP_{ll} + \left(DP_{cap} - DP_{ll}\right) * \left(1 - \left(1 - \frac{(DP_1+DP_2)-DP_{ll}}{DP_{ul}-DP_{ll}}\right)^{\frac{1}{\alpha}}\right) \tag{15}$$

Where

$$\alpha = \frac{DP_{cap} - DP_{ll}}{DP_{ul} - DP_{ll}} \tag{16}$$

$$DP2RO = DP_1 + DP_2 - DP_{dry,tot} \tag{17}$$

DP_1	Adjusted deep percolation
DP_2	Additional recharge from the application of irrigation and movement to non-idealized conditions
$DP_{dry\ tot}$	Model realized rate of deep percolation
DP_{cap}	Maximum rate of realized deep percolation
DP_{ul}	Theoretical point at which the realized rate of deep percolation meets the maximum rate or realized deep percolation, representative of infinity
DP_{ll}	Rate of deep percolation at which the model begins to taper off the realized rate of deep percolation
DP2RO	Recharge converted to runoff due to the recharge cap limit

The recharge realized by the model and the additional runoff is distributed to monthly values proportional to the initial recharge rates.

Working forward from Equation 6, the water balance can be rewritten as shown in Equation 18 below[4].

$$P - ET_{dry,adj} - DP_{dry,tot} - DP2RO - RO_1 - RO_2 - ET_{trans} = \Delta SWC \tag{18}$$

P	Precipitation
$ET_{dry,\ adj}$	Adjusted dryland ET
$DP_{dry\ total}$	Model realized rate of deep percolation
DP2RO	Recharge converted to runoff due to the recharge cap limit
RO_1	Adjusted runoff
RO_2	Additional runoff from the application of irrigation and movement to non-idealized conditions
ET_{trans}	Runoff and deep percolation from CROPSIM converted into non-beneficial ET
ΔSWC	Change in soil water content

To calculate the water balance parameters for irrigated crops, WSPP uses the distributed CROPSIM output for the irrigated crops, the dryland crop ET, and the volume of irrigation applied to the crop[5]. Similar to the dryland calculation, the water balance coming out of CROPSIM (Equation 6) is maintained, keeping precipitation and change in soil water content constant. Furthermore as described in Equations 11-13, a potential adjustment can be made to runoff and deep percolation.

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[4] Note that NIR is equal to zero.

[5] For the LPMT model, the irrigation volumes developed in the IAD program were used.

ET gain is the increase in beneficial consumptive use from the application of irrigation water. Over the entire irrigation season, the marginal increase in ET gain from the application of additional irrigation water is subject to diminishing returns. This process is defined by Equation 19.

$$ET_{gain} = \begin{cases} CIR * \left(1 - \left(1 - \frac{Irr_{crop,irr\ type}}{GIR}\right)^{\frac{1}{\beta}}\right) & Irr_{crop,irr\ type} < GIR \\ ET_{sea,max,irr} - ET_{sea,max,dry} & Irr_{crop,irr\ type} \geq GIR \end{cases} \tag{19}$$

ET_{gain}	Increase in ET from the application of irrigation water
CIR	Consumptive irrigation requirement - the additional amount of ET that a plant must use to maximize its yield potential over a dryland crop; defined in Equation 20

$$CIR = ET_{sea,max,irr} - ET_{sea,max,dry} \tag{20}$$

GIR	Gross irrigation requirement - the amount of water that needs to be applied in order to meet the net irrigation requirement
β	Water use efficiency term; defined by Equation 21

$$\beta = \frac{CIR}{GIR} \tag{21}$$

$Irr_{crop,\ irr\ type}$	Depth of irrigation water applied to the crop from an irrigation source
$ET_{sea,\ max,\ irr}$	ET needed to meet the max yield potential for an irrigated crop during the growing season
$ET_{sea,\ max,\ dry}$	Dryland ET utilized during the irrigation season

The resultant ET gain was then distributed back to the months based upon: 1) Applied Water > 0 and $ET_{irr} > ET_{dry}$, 2) Applied Water > 0 and $ET_{irr} < ET_{dry}$, and finally any remaining ET gain by 3) Applied Water = 0 and $ET_{irr} > ET_{dry}$. The ET gain is added to the non-irrigated ET to determine the total ET. Finally, an adjustment of the irrigated ET was made to account for differences between the idealized conditions in CROPSIM and those observed in the field (Equation 22).

$$ET_{irr,adj} = ET_{irr} * ADJ_{ET,irr} \tag{22}$$

ET_{irr}	Irrigated ET[6]
$ET_{irr,\ adj}$	Adjusted irrigated ET
$ADJ_{ET,\ irr}$	Irrigated ET adjustment factor

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[6] The irrigated ET is a function of applied water

Next a surface loss[7] was calculated to determine the portion of applied water that was lost directly to non-beneficial consumptive use. These losses are assumed to be a fixed percentage of the total applied volume. Finally, the remaining applied water in excess of the surface losses and ET, while maintaining the change in soil water content from the CROPSIM output, was divided between runoff (RO_2) and deep percolation (DP_2), defined by Equation 23. This water includes both the irrigation inefficiencies and the shift from idealized CROPSIM conditions.

$$RODP_{wt} = MIN\left(MAX\left(\frac{RO_fDP*RO_1}{RO_fDP*RO_1+DP_1}, RO_{min}\right), RO_{max}\right) \tag{23}$$

$RODP_{wt}$	Partitioning factor used to divide water between runoff and deep percolation
RO_fDP	Weighting factor to control the influence of runoff on the partitioning factor
RO_1	Adjusted runoff
DP_1	Adjusted deep percolation
RO_{min}	Minimum partitioning factor
RO_{max}	Maximum partitioning factor

Finally, the WSPP program allows for upper limits to be applied to irrigated recharge rates in the same way they are applied to the dryland crops (Equations 14-17). The results from the irrigated calculations are summarized in Equation 24) and are equivalent to the results found in Equation 6 for an irrigated crop. The partitioning of the applied irrigation is further illustrated in **Figure 6**.

$$P + Irr_{crop,irr\ type} - SL - ET_{irr,adj} - DP_{irr,tot} - DP2RO - RO_1 - RO_2 - ET_{trans} = \Delta SWC \tag{24}$$

P	Precipitation
$Irr_{crop,\ irr\ type}$	Depth of irrigation water applied to the crop from an irrigation source
SL	Surface losses
$ET_{irr,\ adj}$	Adjusted irrigated evapotranspiration
$DP_{irr,\ tot}$	Total irrigated deep percolation
DP2RO	Recharge converted to runoff due to the recharge cap limit
RO_1	Adjusted runoff
RO_2	Additional runoff from the application of irrigation and movement to non-idealized conditions
ET_{trans}	Runoff and deep percolation from CROPSIM converted into non-beneficial ET
ΔSWC	Change in soil water content

The results were then scaled to the cell level by multiplying the water balance results by the number of crop acres serviced by the irrigation method within the cell. Finally, the cell totals were calculated by summing all the crop irrigation method combinations present within the cell.

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[7] Surface loss in this context refers to irrigation water lost during application; drift, evaporation, interception, etc…

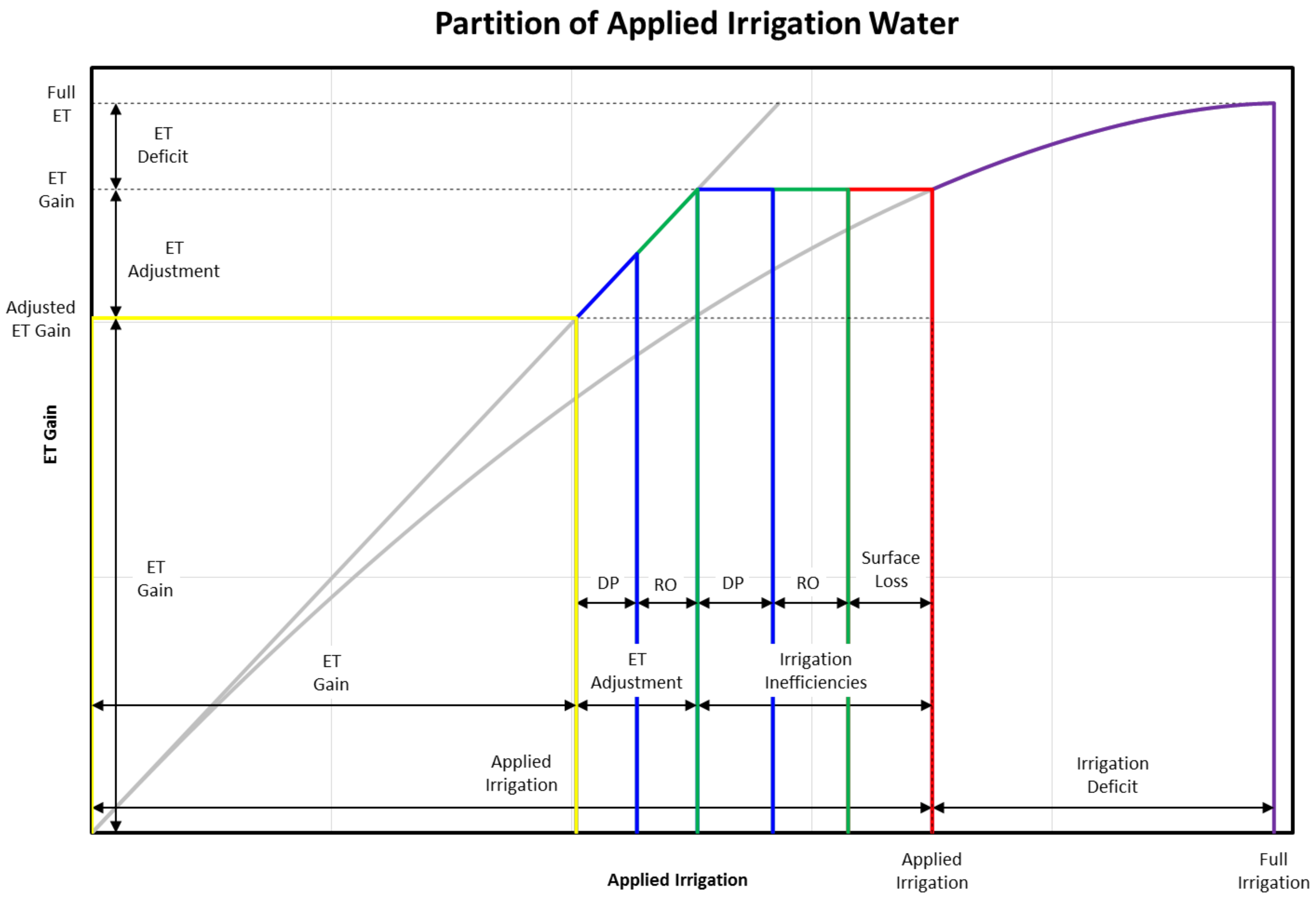

Figure 6. Partitioning a depth of applied irrigation between ET, RO, DP, and surface losses**.**

*terms are exaggerated to illustrate concept.

5.3. Make Well

The primary purpose of the Make Well program combines the various forms of pumping data into a set of annual files developed for the groundwater model in the .WEL format. During this process the program incorporates the well penetration information to assign pumping rates to the appropriate aquifer layer.

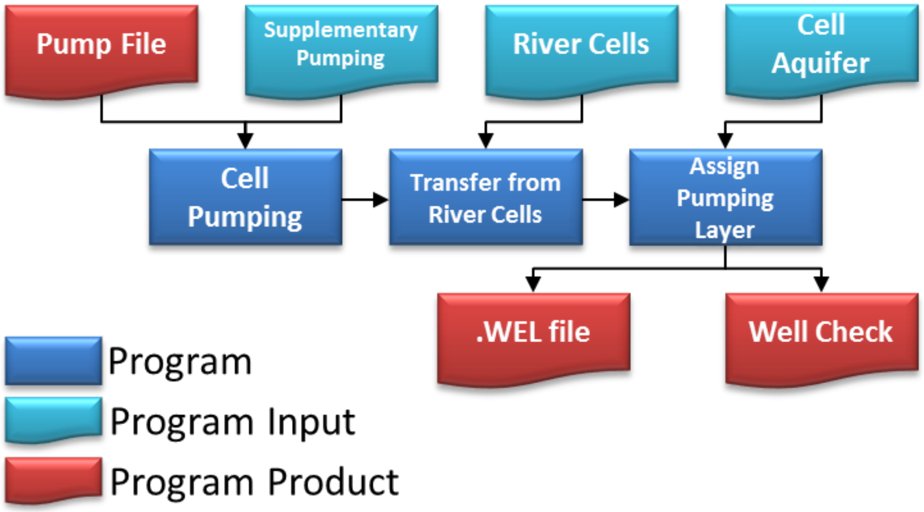

Figure 7. Flow chart depicting the inputs, outputs, and major functions of the Make Well program.

The only required source is the groundwater pumping from the WSPP program. However, the program can accommodate other sources such as municipal & industrial pumping, or supplementary pumping[8].

5.4. Compile Well

The Compile Well program was a simple program developed to combine the annual pumping files with the correct headers into a single file ready for use in the groundwater model. A program Schematic would not materially assist in reviewing the Compile Well's source code.

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[8] Supplementary pumping refers to estimates of pumping created outside of the RSWB model but are merged into the pumping file for the ground water model.

5.5. Make Recharge

The Make Recharge program combined the various forms of recharge data into a set of annual files formatted for use in the groundwater model in the .RCH format. These sources include direct agricultural recharge, indirect agricultural recharge, canal recharge, and supplementary recharge[9].

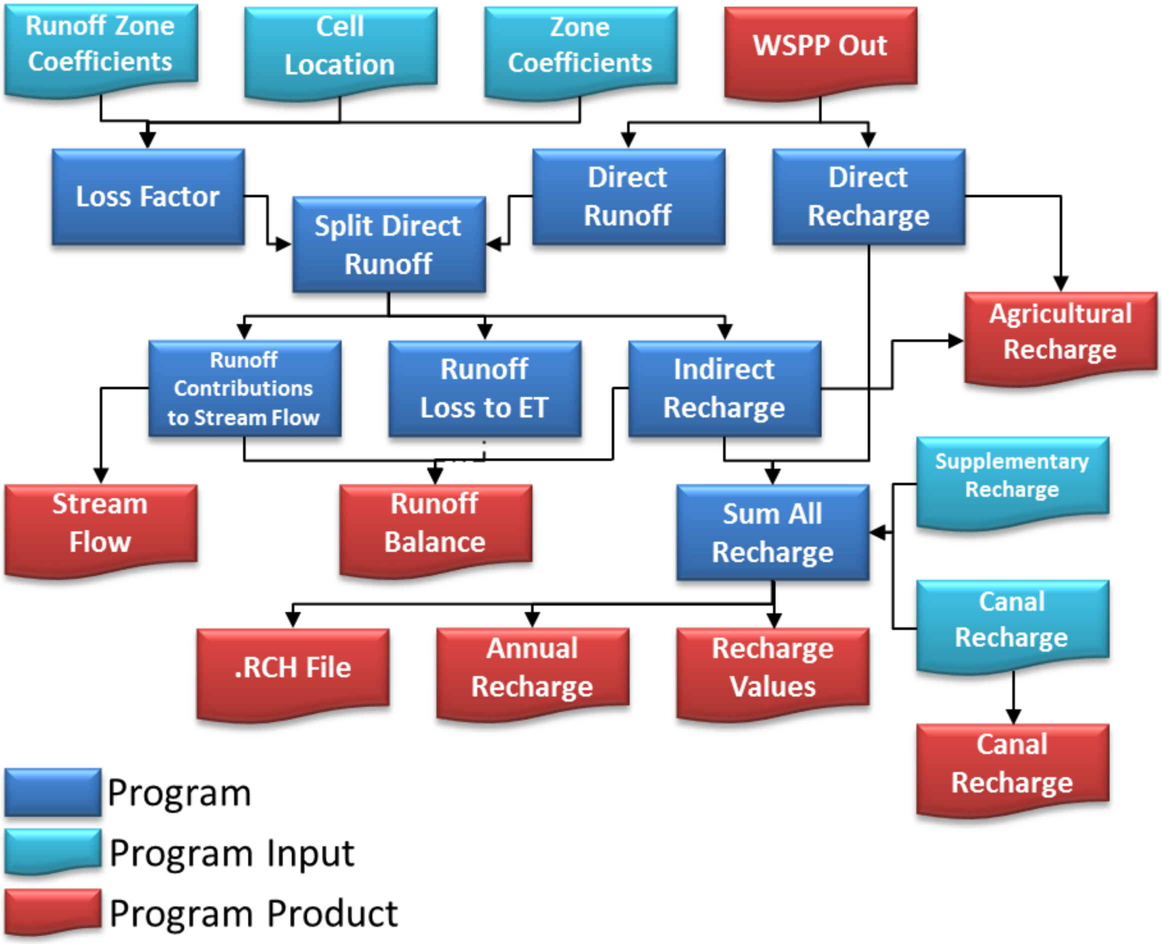

Figure 8. Flow chart depicting the inputs, outputs, and major functions of the Make Recharge program.

The make recharge program is responsible for estimating the indirect recharge. Indirect recharge is the additional recharge resulting from transit losses between the field and the stream gauge. It is a function of direct agricultural runoff from a cell, a loss per mile variable, soil type, and the distance from the cell to the stream gauge at the end of the runoff zone. The runoff loss is divided into non-beneficial consumptive use (ET) and recharge (Equations 25-28).

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[9] Supplementary recharge refers to estimates of recharge that were created outside of the RSWB Model but were merged into the recharge dataset provided to the ground water model.

$$RO = SF + RO2DP + RO2ET \tag{25}$$

$$SF = RO * (1 - LossFactor) \tag{26}$$

$$RO2DP = RO * LossFactor * \%2Rch \tag{27}$$

$$RO2ET = RO * LossFactor * (1 - \%2Rch) \tag{28}$$

RO	Runoff
SF	Runoff contributions to streamflow
RO2DP	Runoff transmission losses to recharge
RO2ET	Runoff transmission losses to non-beneficial consumptive use
LossFactor	Portion of field runoff lost to recharge or ET during transit from field to stream gauge; calculated using Equation 29

$$LossFactor = Min(1 - e^{-lpm*Mi2Gauge}, 1.0) \tag{29}$$

%2Rch	Partitioning factor splitting the transmission losses between recharge and ET
Lpm	Loss per mile factor
Mi2Gauge	Distance between the centroid of a cell and the stream gauge identifying the accumulation point of the basin

5.6. Compile Recharge

The Compile Recharge program is a simple program developed to combine the annual .RCH files with the appropriate headers into a single file ready to be input into the groundwater Model. A program schematic would not materially assist in reviewing the Compile Recharge's source code.

5.7. WSPP Report

The WSPP Report program is also a simple program developed to compile the water balance parameters into annual summary files. Summaries are created on each the regional, county, coefficient zone, and runoff zone basis. Within each of these areas annual and monthly summaries are created for combinations of soil, crop, and irrigation source.

5.8. Compile WSPP Report

The Compile WSPP Report program combines the annual summary files from the WSPP Report into a set of summary files.

6. RSWB Model Inputs

6.1. Model Grid

Defining the area to be modeled is a first step in model development. For the RSWB the LPMT groundwater flow model grid was adopted. The grid consists of 98,700 cells of 160 acres organized in 350 rows and 282 columns. Of these cells, the 64,438 cells which are active over the principal and bedrock aquifers the groundwater model are also active in the watershed model.

6.2. Model Period

The LPMT model was developed from 1960 through 2013. For the period 1960 to 1985 the LPMT Model used annual stress periods; switching to monthly stress periods from January 1986 through December 2013. All RSWB results were developed on a monthly time step, which in turn were scaled to annual value to match the groundwater model.

6.3. Soils

Soil characteristics influence how crops respond to climatic and management conditions. Soils can be thought of acting like miniature reservoirs that store and release water for vegetative growth (ET), allow the water to drain as recharge, or restrict the water from infiltrating thus resulting in runoff.

Within the RSWB model, a cell's assigned soil type served as a link to the results from the CROPSIM model. To build this link, each cell was assigned a CROPSIM soil type. This was accomplished in a three-step process. The first step was to identify the soils present in the simulated area. Statsgo2, from the Natural Resources Conservation Service (NRCS), is a database which contains the spatial distribution of soils (Figure 9).

Within the model domain, numerous Statsgo2 soils classifications are present. To simplify the modeling process, the soils were grouped together with soils which exhibit similar properties. To maintain congruency with the CROPSIM modeling practices, three characteristics were used: water holding capacity, hydrologic soil group, and distance to groundwater. This process reduced the number of soils in the model to 26 soil classifications (Figure 10).

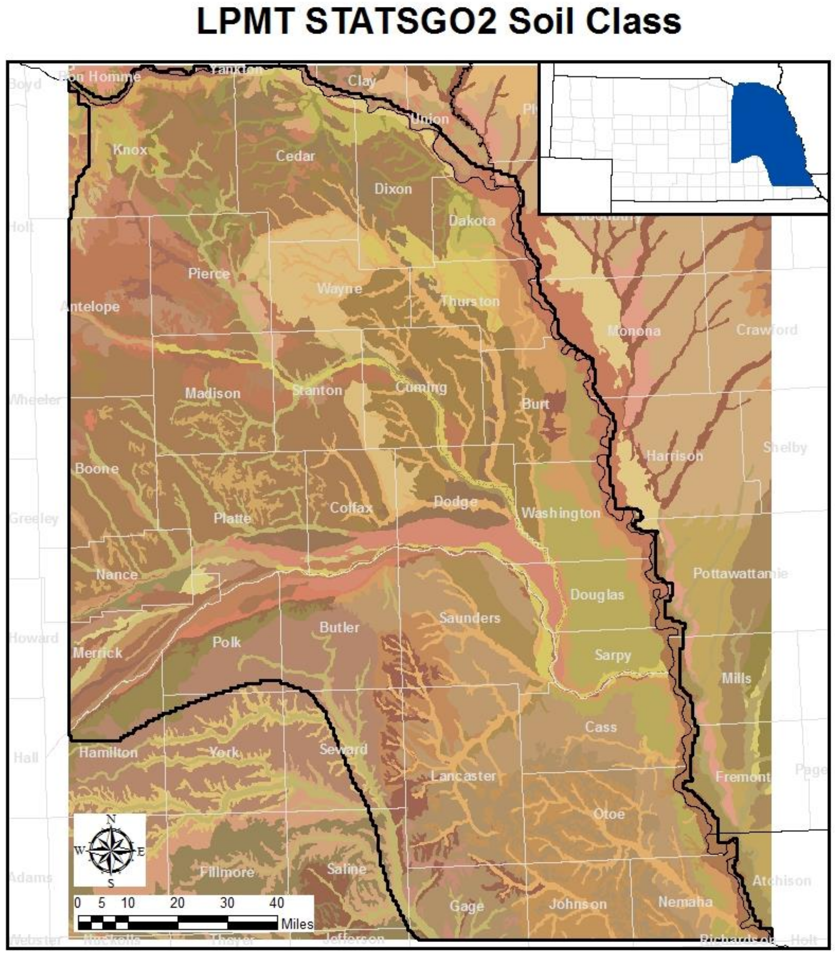

Figure 9. Statsgo2 soil coverage.

Next, the predominant soils class within each cell was determined. The CROPSIM soils map was overlaid with the model grid. The area of each soil within the cell was calculated. Finally, the soil class covering the largest area was identified and assigned to each cell (Figure 11) leaving 22 soil classes.

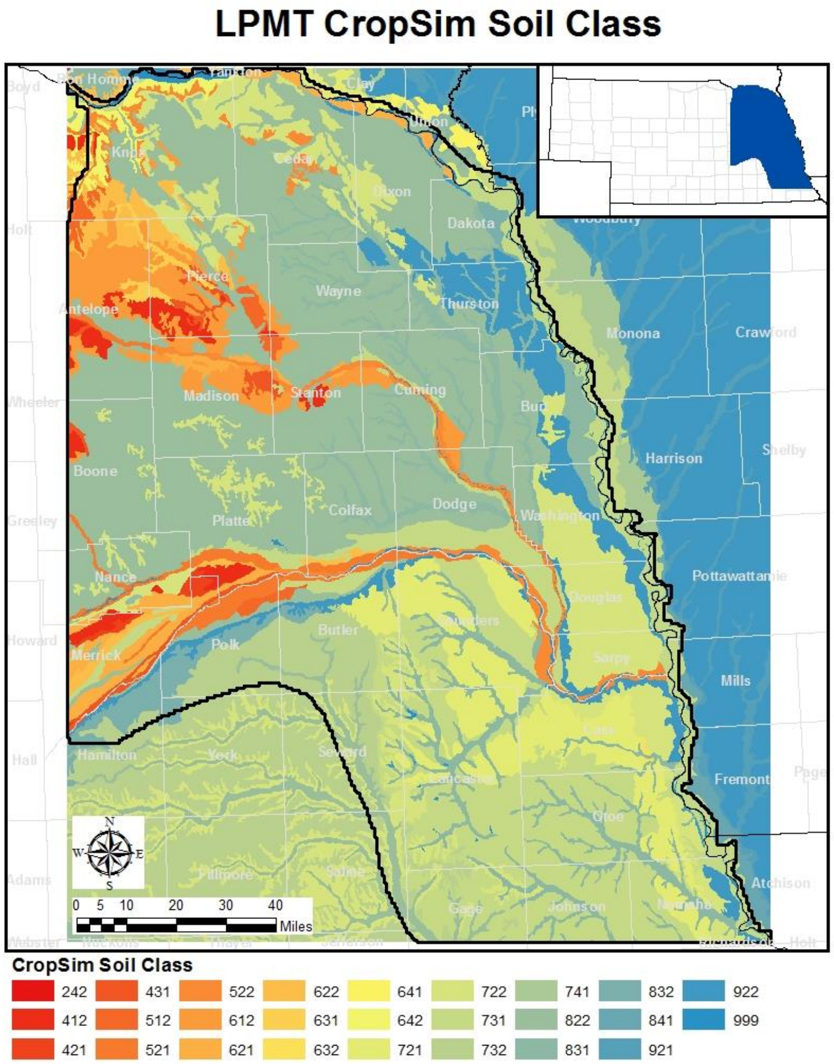

Figure 10. CropSim soil class assignment for each Statsgo 2 soil.

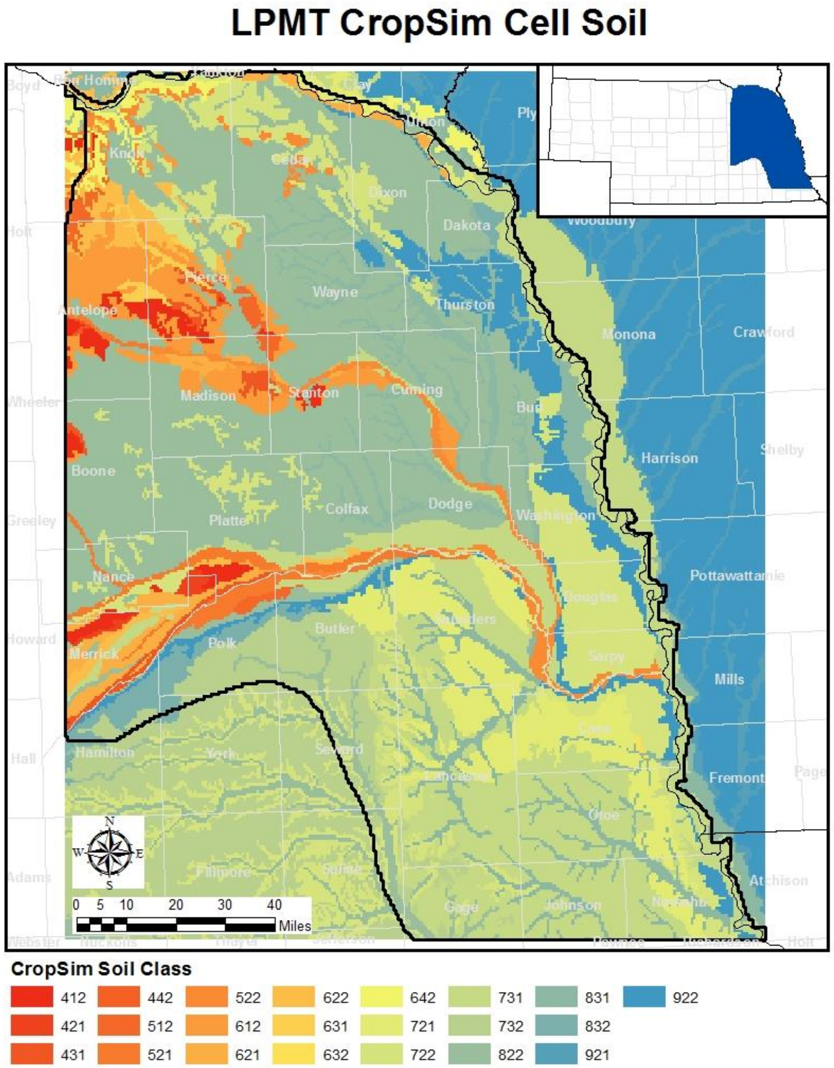

Figure 11. Assignment of the dominant CropSim soil class to each cell.

6.4. Climate

Climatic conditions also greatly influence vegetative growth; and thus, are a significant input into the CROPSIM model. Weather data was collected from 50 weather stations in and around the model domain (Figure 12). The 50 weather stations are listed in Table 1.

Precipitation, maximum temperature, and minimum temperature were downloaded from the High Plains Regional Climate Center for the historic period of record. The weather data was reviewed for completeness and reliability. Following the quality control efforts, the information was run through the climate model and prepared into .WEA files for use in the CROPSIM model.

Within the model domain average precipitation ranges from 23" in the north and west increasing in wetness to roughly 34" in the south east segment of the model. Figure 12 show the average annual precipitation for LPMT model domain.

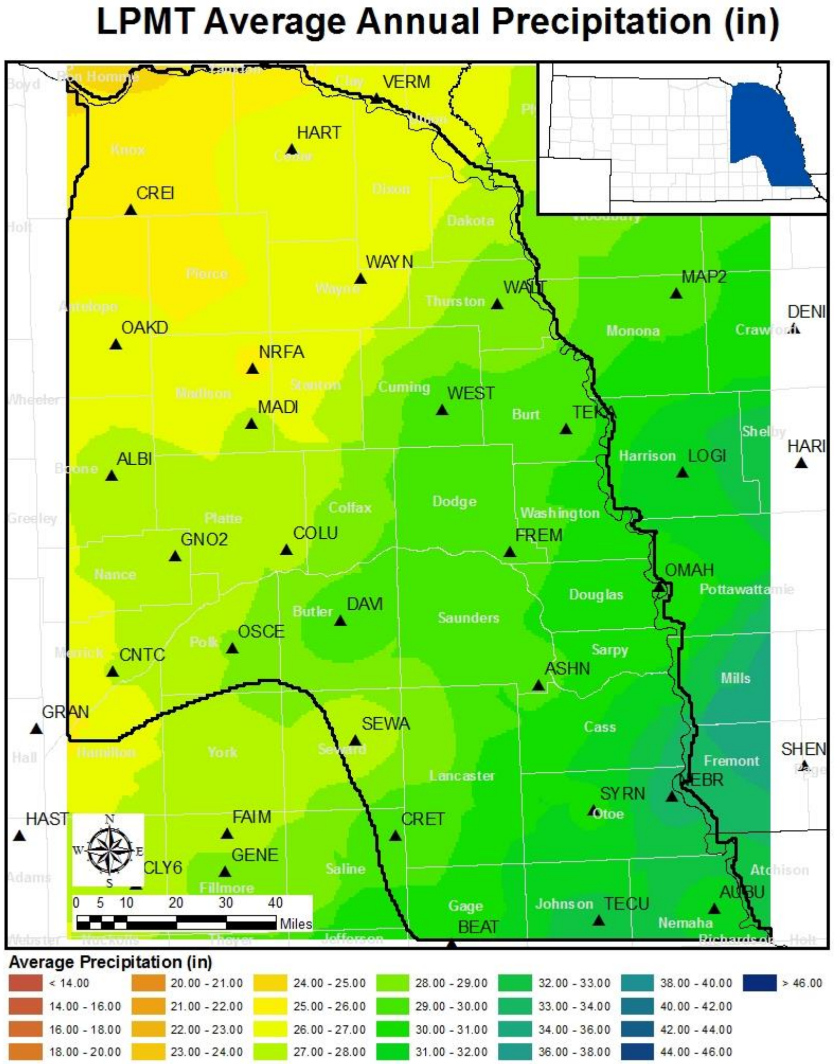

Figure 12. Location of the weather stations and average annual precipitation in the LPMT model domain.

Table 1. NWS weather station used in the LPMT model.

Index	Station	State	Station Code	NWS code	Latitude	Longitude	Elevation
1	Albion[†]	NE	ALBI	c250070	41.69	-98.00	1,790
2	Ashland 2	NE	ASHN	c250375	41.04	-96.38	1,070
3	Auburn 5 ESE	NE	AUBU	c250435	40.37	-95.75	930
4	Bartlett 4 S	NE	BART	c250525	41.87	-98.55	2,219
5	Beatrice	NE	BEAT	c250620	40.25	-96.75	1,220
6	Butte	NE	BUTT	c251365	42.91	-98.85	1,811
7	Clay Center 6 ESE[¥]	NE	CLY6	c251680	40.50	-97.94	1,734
8	Central City	NE	CNTC	c251560	41.12	-98.01	1,695
9	Columbus 3 NE	NE	COLU	c251825	41.46	-97.33	1,450
10	Creighton[‡]	NE	CREI	c251990	42.46	-97.90	1,660
11	Crete	NE	CRET	c252020	40.62	-96.95	1,435
12	David City	NE	DAVI	c252205	41.25	-97.13	1,610
13	Denison	IA	DENI	c132171	42.04	-95.33	1,401
14	Fairbury	NE	FAIB	c252820	40.07	-97.17	1,350
15	Fairmont[‡]	NE	FAIM	c252840	40.64	-97.59	1,640
16	Fremont	NE	FREM	c253050	41.43	-96.47	1,180
17	Geneva	NE	GENE	c253175	40.53	-97.60	1,630
18	Genoa 2 W	NE	GNO2	c253185	41.45	-97.76	1,590
19	Grand Island WSO Airport	NE	GRAN	c253395	40.96	-98.31	1,840
20	Greeley	NE	GREE	c253425	41.55	-98.53	2,020
21	Harlan 1 N	IA	HARI	c133632	41.65	-95.33	1,290
22	Hartington	NE	HART	c253630	42.62	-97.26	1,370
23	Hastings 4 N	NE	HAST	c253660	40.65	-98.38	1,938
24	Hebron	NE	HEBR	c253735	40.17	-97.59	1,480
25	Le Mars	IA	LEMA	c134735	42.78	-96.15	1,195
26	Logan	IA	LOGI	c134894	41.64	-95.79	990
27	Madison 2 W[₮]	NE	MADI	c255080	41.83	-97.45	1,580
28	Mapleton 2	IA	MAP2	c135123	42.16	-95.78	1,200
29	Nebraska city 2 NW	NE	NEBR	c255810	40.70	-95.89	1,055
30	Norfork Karl Stefan Airport	NE	NRFA	c255995	41.99	-97.44	1,551
31	Oakdale	NE	OAKD	c256135	42.07	-97.97	1,710
32	Omaha Eppley Airfield	NE	OMAH	c256255	41.31	-95.90	982
33	O'Neill	NE	ONEI	c256290	42.46	-98.66	1,990
34	Osceola	NE	OSCE	c256375	41.18	-97.55	1,640
35	Pawnee City	NE	PAWN	c256570	40.12	-96.16	1,240
36	Red Cloud	NE	REDC	c257070	40.10	-98.52	1,720
37	Red Oak	IA	REDO	c136940	41.00	-95.24	1,040
38	Seward	NE	SEWA	c257715	40.90	-97.09	1,445

Table 1. NWS weather station used in the LPMT model.

Index	Station	State	Station Code	NWS code	Latitude	Longitude	Elevation
39	Shenandoah	IA	SHEN	c137613	40.77	-95.38	975
40	St Paul 4 N	NE	STPA	c257515	41.21	-98.46	1,796
41	Superior 4 E	NE	SUPE	c258320	40.03	-97.98	1,620
42	Syracuse	NE	SYRN	c258395	40.67	-96.19	1,100
43	Tecumseh	NE	TECU	c258465	40.35	-96.19	1,110
44	Tekamah	NE	TEKA	c258480	41.78	-96.23	1,140
45	Tyndall	SD	TYND	c398472	42.99	-97.86	1,420
46	Vermillion 2 SE[¥]	SD	VERM	c398622	42.76	-96.92	1,190
47	Walthill	NE	WALT	c258935	42.15	-96.48	1,280
48	Wayne	NE	WAYN	c259045	42.24	-97.01	1,465
49	West Point	NE	WEST	c259200	41.85	-96.71	1,310
50	Yankton	SD	YANK	c399502	42.88	-97.36	1,180

[†] Weather station stopped collecting data after 2007

[‡] Weather station stopped collecting data after 2010

[Ŧ] Weather station stopped collecting data after 2011

[¥] Weather station stopped collecting data after 2012

6.5. Water Balance Parameters

The weather data from each station was run through the CROPSIM Model to simulate the water balance for each crop, soil, and irrigation as described in Section 4.3. The spatial and temporal distribution model, in conjunction with the soil distribution, was used to distribute the water balance results of the CROPSIM model to each cell in the model domain. This process created annual files for each water balance parameter (P, NIR, DP, RO, and ET) for each combination of crop and irrigation method. Figure 13 show the average annual NIR for corn. The image depicts both the influence of both precipitation and soil by mimicking the patterns seen in Figure 12 and Figure 11 respectively.

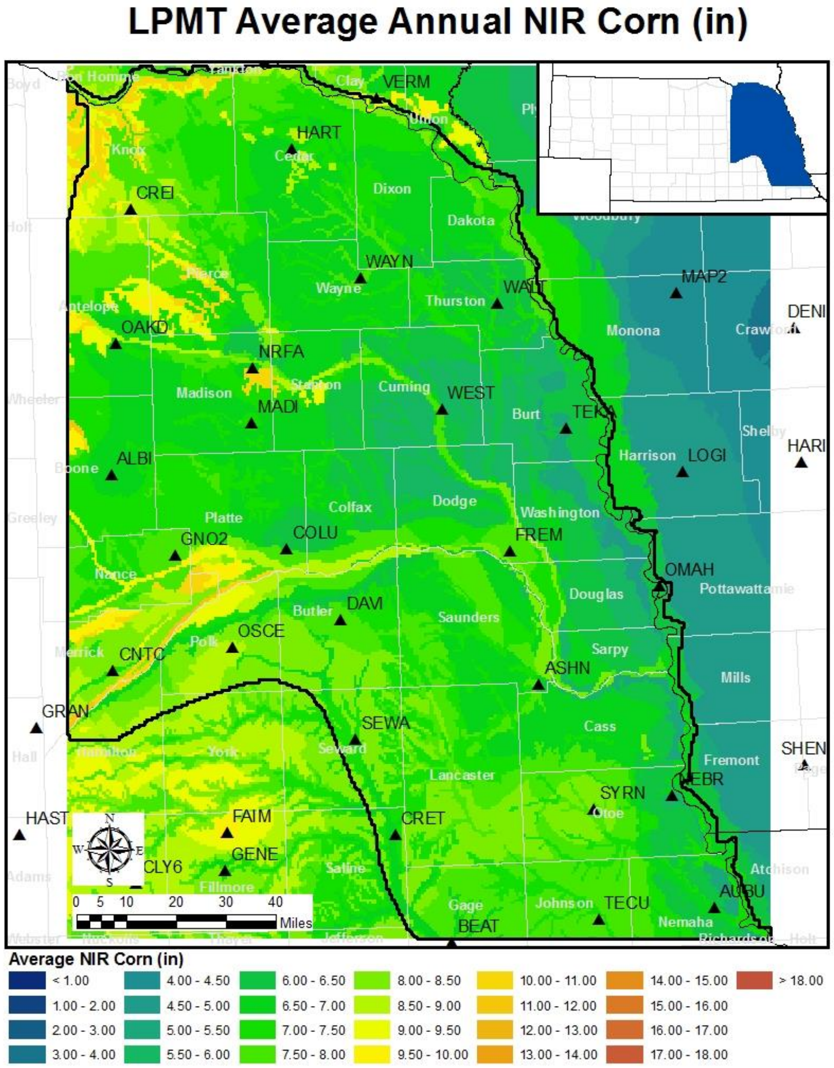

Figure 13. Average annual net irrigation for corn within the LPMT model domain.

6.6. Land Use

Land use inputs specify the types of crops being grown in the watershed; as well as if they are being irrigated and from which source (dryland, groundwater only, surface water only, or comingled). This definition is used to determine the initial water balance parameters and scale the point results to the field level. Land use was developed on a cell basis by DNR. The area within each cell was defined by the combination of crop coverage and irrigation source. The balance of land was assigned as dryland pasture. The LPMT model considers in addition to dryland pasture; corn, alfalfa, soybeans, and small spring grains. Figure 14 shows the development of irrigated acres over the modeled period.

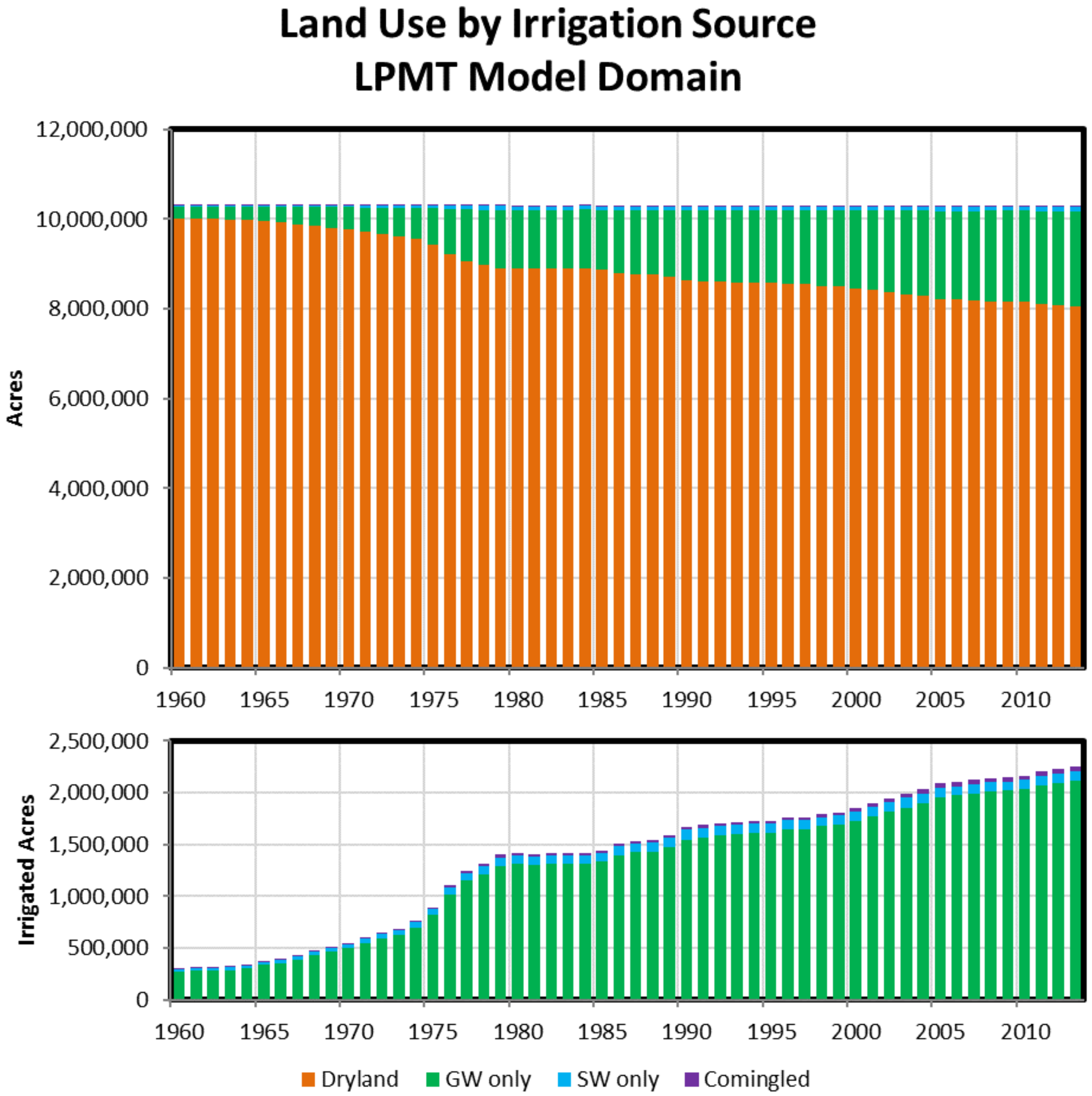

Figure 14. Development of irrigated acres within the LPMT model domain.

6.7. Application Efficiency

The application efficiency is the ratio of the net irrigation to gross irrigation. It is often dependent upon the techniques used to physically apply water to the field. Within the watershed model, the application efficiency was assigned based upon irrigation source. Acreage irrigated with surface water was assumed to be flood irrigated and was assigned an application efficiency of 0.65 for all years. Acres irrigated with groundwater were assumed to be irrigated by sprinkler systems. The application efficiency was set at 0.70 between 1960 and 1970. To represent improving technology and improved irrigation management techniques, groundwater application efficiency was then linearly trended between 0.70 in 1970 and 0.85 in 1993. The application efficiency remained at 0.85 through 2013.

6.8. Pumping Aquifer Assignment

The LPMT model is a two layer model; the principal or Ogallala Aquifer (layer 1), and the bedrock or Dakota Aquifer (layer 2). This is an important consideration for assigning pumping to the appropriate layer while creating the .WEL file. Without metered data and field well relationships, the LPMT model uses a virtual pumping technique where the pumping is assumed to occur in the center of the cell where it is applied. The layer assignment for the pumping was then based upon the location of the cell and existence of any well records within the cell given the following priority:

1. Cell contains a high capacity[10] well with a pumping elevation above top of bedrock – Layer 1
2. Cell contains a high capacity well with a pumping elevation below top of bedrock – Layer 2
3. Cell is located over the Dakota Aquifer and contains a low capacity well with a pumping elevation above the top of bedrock – Layer 1
4. Cell is located over the Dakota Aquifer and contains a low capacity well with a pumping elevation below the top of bedrock – Layer 2
5. Cell is located over the Dakota Aquifer with no well records – 75% to Layer 1; 25% to Layer 2
6. Cell is not located over the Dakota Aquifer with no well records – Layer 1

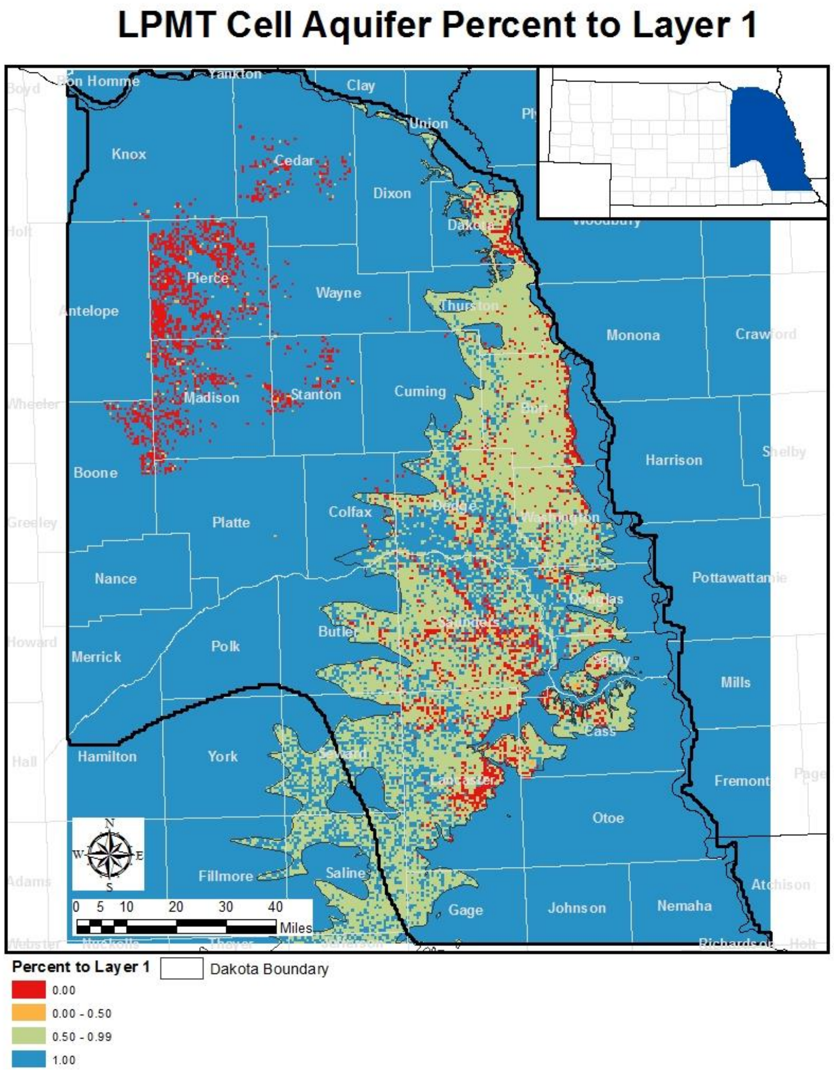

Figure 15. Cell layer assignments.

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[10] High capacity has been defined as 50 gallons per minute

6.9. River Cells & Pumping Transfer

There are limitations in the groundwater model regarding the number of inputs and outputs per cell the model can accommodate. These restrictions limit the capability of the groundwater model to have river cells and pumping in the same cell; rendering it necessary to move pumping from these cells to adjacent cells.

The river cell assignment was obtained from the groundwater model (Figure 17). Each river cell was assigned a set of adjacent cells where the pumping would be relocated. A creep function was used to identify the nearest cells which were active cells and not river cells. Any relocated pumping was distributed uniformly to the lowest indexed non-river cell(s) closest to the original pumping cell per the progression pattern defined in Figure 16.

1 5	2 4	3 3	4 4	5 5
6 4	7 2	8 1	9 2	10 4
11 3	12 1	13 Pumping Cell	14 1	15 3
16 4	17 2	18 1	19 2	20 4
21 5	22 4	23 3	24 4	25 5

Figure 16. Progression of cells selection for river cell pumping transfer.

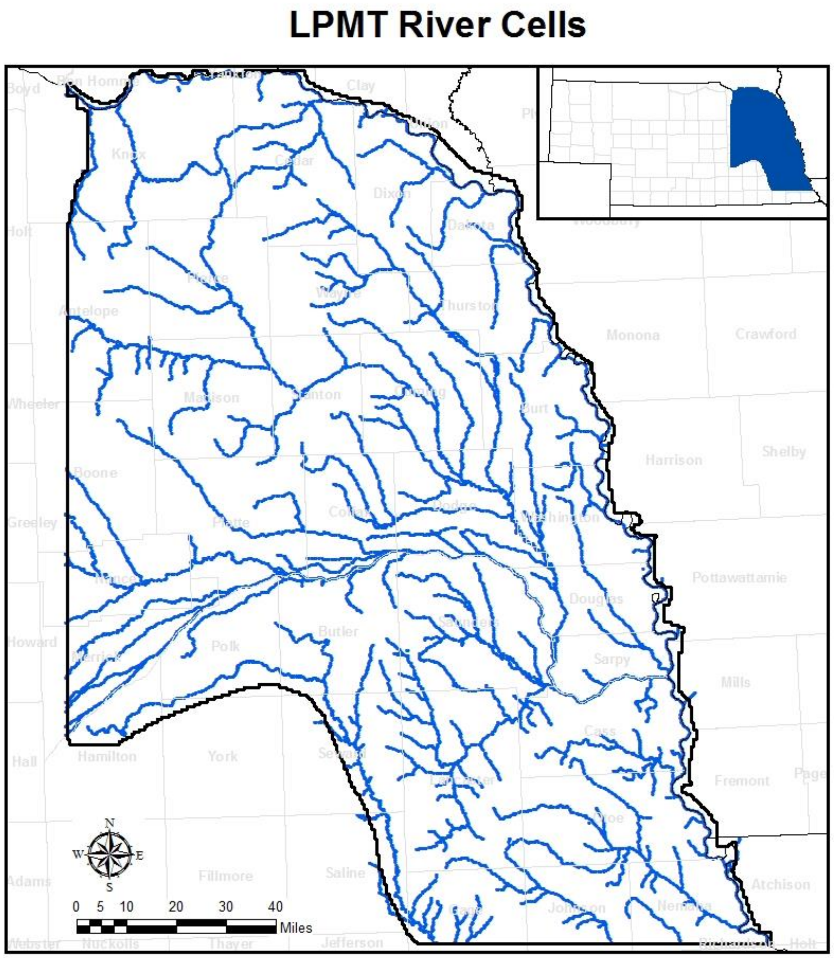

Figure 17. Groundwater model river cells.

6.10. Model Regions

The RSWB employs regions to aid in the spatial calibration of the model and interact with other models as part of a larger integrated model. The input regions allow for adjustments to sub-areas independent of the rest of the model domain in order to reflect significant localized conditions. The RSWB uses two types of regions; runoff zones and coefficient zones.

Runoff Zones

Runoff zones represent a delineation of the model domain by selected watershed boundaries. These areas consist of the land area that drains to a certain point; usually designated by a stream gauge. The RSWB model consists of 74 runoff zones (Figure 18). Of these zones 1-62 represent the drainage area to a stream gauge, while zones 63-74 consist of the boundary area along the model perimeter. This discretization of the model domain was created with the expectation that the LPMT groundwater and watershed models will eventually be paired with a surface water operation model with the runoff zones acting as nodes for the transfer of data between models.

The runoff zones are used to calibration the portion of the field runoff which contributed to stream flow. The runoff zone uses the loss per mile parameter to regulate the rate at which runoff is lost during transit from the field to the stream gauge. The parameters can be found in Table 8**Error! Reference source not found.** of Appendix A.

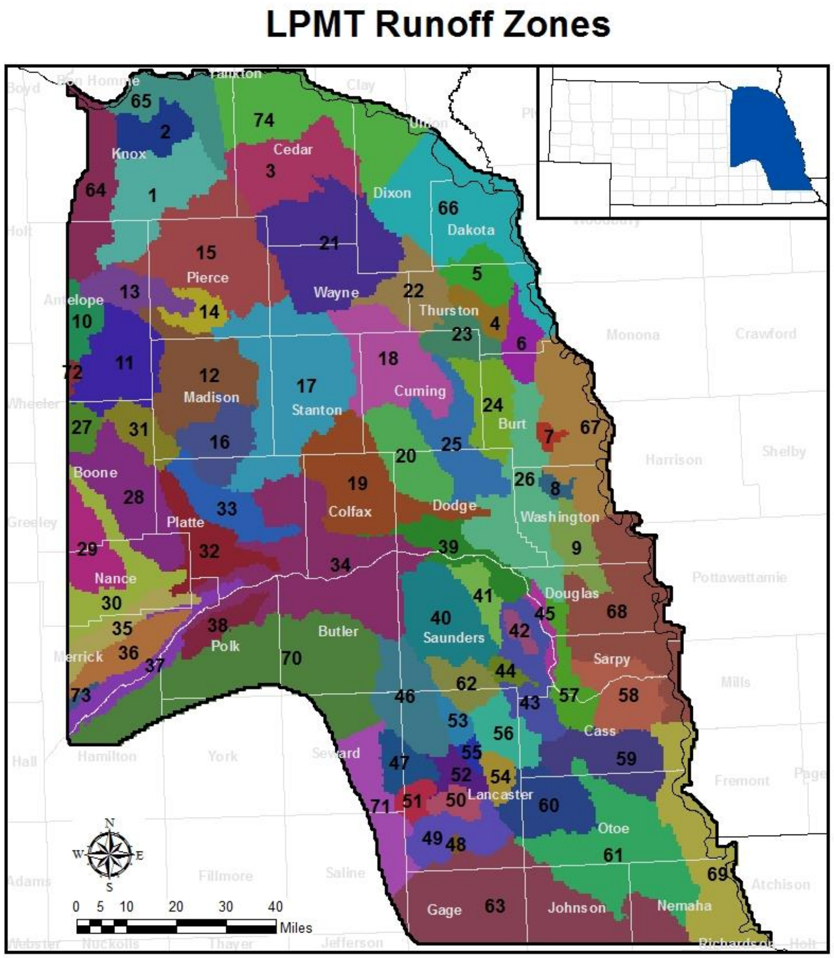

Figure 18. LPMT model runoff zones

Coefficient Zones

Coefficient zones represent a geographical group of cells which exhibit similar water balance responses. The LPMT RSWB includes 14 coefficient zones (Figure 19). These zones were created by combining the runoff zones to investigate different drainage basins within the LPMT. Furthermore, each coefficient zone is sub-divided by soil type.

Each coefficient zone soil combination contains a set of the RSWB adjustment coefficients used for the calibration of the watershed model. There are fifteen different adjustment coefficients:

1. Dryland ET Adjustment ($ADJ_{ET,\,dry}$): Adjusts ET for the difference between the results from the CROPSIM model and realized field conditions for dryland crops
2. Irrigated ET Adjustment ($ADJ_{ET,\,irr}$): Adjusts ET for the difference between the results from the CROPSIM model and the realized field conditions for the irrigated crops
3. NIR Target ($Target_{NIR}$): Adjusts the depth of irrigation water applied to the crop
4. Application Efficiency Adjustment – Groundwater ($ADJ_{AE,\,GW}$): Adjusts the application efficiency of groundwater irrigated lands to account for spatial differences and technological advances
5. Surface Loss Fraction – Groundwater (FSL_{GW}): Specifies a percentage of applied groundwater irrigation water that is lost to non-beneficial consumptive use
6. Dryland ET to Runoff (DryET2RO): Specifies the portion of the dryland ET adjustment that is converted to runoff with the remainder becoming deep percolation

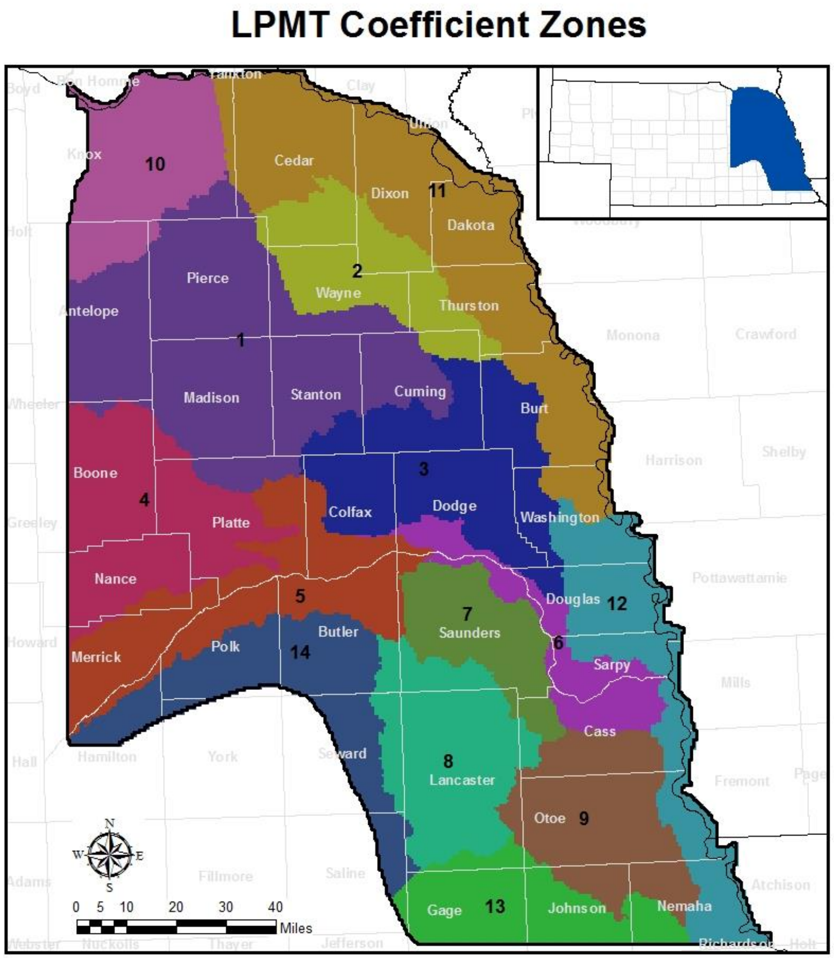

Figure 19. LPMT model coefficient zones.

7. Application Efficiency Adjustment – Surface Water ($ADJ_{AE, SW}$): Adjusts the application efficiency of surface water irrigated lands to account for spatial differences and technological advances

8. Surface Loss Fraction Surface Water (FSL_{SW}): Specifies a percentage of applied surface water irrigation water that is lost to non-beneficial consumptive use

9. Percent to Recharge (%2Rch): Specifies the portion of the transmission losses from overland runoff that area converted to recharge with the remainder going to non-beneficial consumptive use

10. Deep Percolation Adjustment (ADJ_{DP}): Adjusts the deep percolation results from the CROPSIM model with the change being converted to non-beneficial consumptive use

11. Runoff Adjustment (ADJ_{RO}): Adjusts the runoff results from the CROPSIM model with the change being converted to non-beneficial consumptive use

12. Comingled Split (CM_{split}): Specifies the portion of the NIR that is met by surface water deliveries

13. Deep Percolation Lower Threshold (DP_{ll}): Sets the lower limit at which the RSWB model begins to taper off annual deep percolation rates

14. Deep Percolation Cap (DP_{cap}): Sets the maximum rate of deep percolation the program will allow

15. Runoff Weighting Factor ($RO_{f}DP$): Weighting factor used to influence the effect of runoff on the irrigated partitioning factor ($RODP_{wt}$)

The calibrated parameters can be found in Table 6 of Appendix A.

6.11. Canal Recharge

Canal recharge represents the transmission losses accrued through the delivery of surface water through canal systems. Currently there is no canal recharge incorporated into the LPMT watershed model.

6.12. Municipal and Industrial Pumping

Municipal and industrial (M&I) pumping in the LPMT model area was divided into 3 categories: Lincoln municipal pumping; Omaha municipal pumping; and the LPMT M&I pumping. The LPMT M&I pumping was extracted from the statewide M&I database (cite statewide M&I). The Lincoln and Omaha municipal pumping was not included in the statewide data set; necessitating the creation of pumping estimates for Lincoln and Omaha.

Public wells identified as the source for either Lincoln or Omaha were identified (Figure 21). The estimated pumping for municipal wells was developed using a per capita pumping technique. Annual population estimates were made by interpolating census results (Equation 30).

$$pop_i = pop_1 + (pop_2 - pop_1)\left(\frac{year_i - year_1}{year_2 - year_1}\right) \quad (30)$$

pop	Population
year	year

Table 2. Populations of Lincoln, NE and Omaha, NE

	Population	
Year	**Lincoln**	**Omaha**
1930	75,933	214,006
1940	81,984	223,844
1950	98,884	251,117
1960	128,521	301,598
1970	149,518	346,929
1980	171,932	313,939
1990	191,972	335,795
2000	225,581	390,007
2010	258,379	408,958

Utilizing the per capita pumping distributions and annual population estimates, the total volume of water pumped by each municipality can be estimated. This volume is then split between all the active wells feeding the municipality; weighted and limited by the relative capacity of the well (Equation 31).

$$Pump_{well,i} = Pop_j * PPC_i * \frac{Cap_{well}}{Cap_{muni,j}} \quad (31)$$

$Pump_{well,\ i}$	Pumping estimate for a municipal well
Pop	Municipal population
PPC	Per capita pumping
Cap_{well}	Capacity of the well
$Cap_{muni,\ j}$	Total municipal capacity in the given year

Figures 20-21 show the spatial distribution of the pumping from the municipal and industrial pumping. The annual pumping volumes for municipal & industrial, Omaha municipal, and Lincoln municipal are shown in Figures 22-24; while the total M&I pumping is shown in Figure 25.

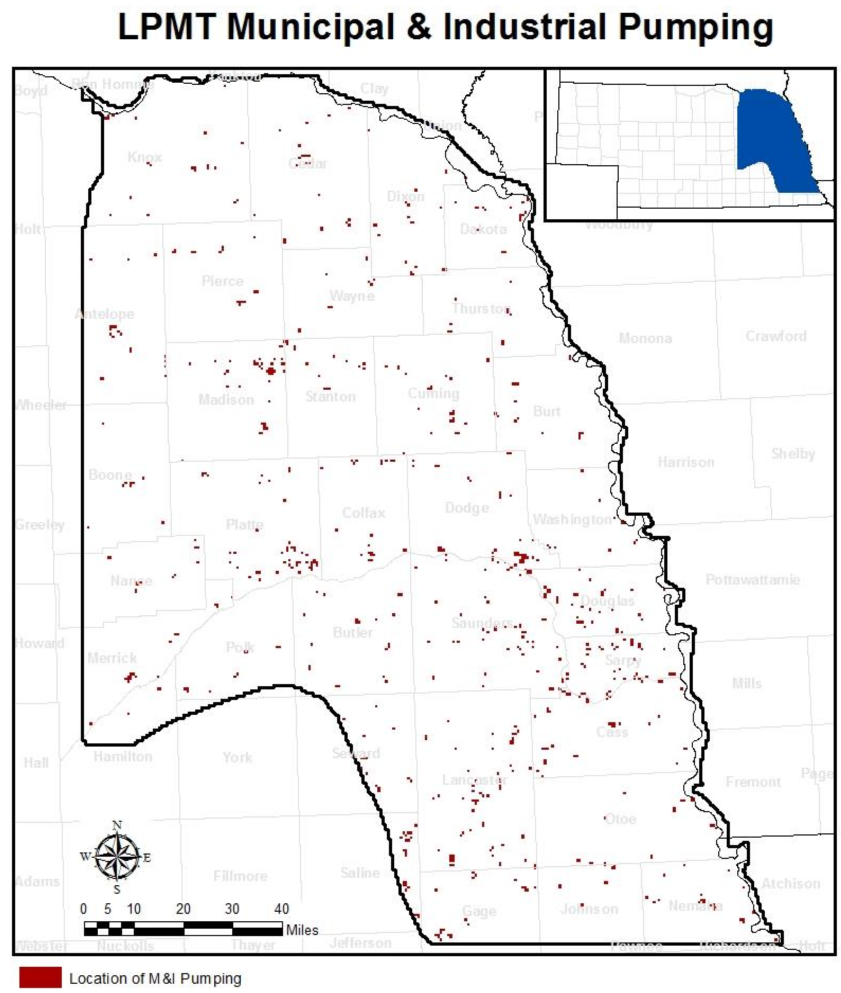

Figure 20. Distribution of LPMT Municipal and Industrial Pumping.

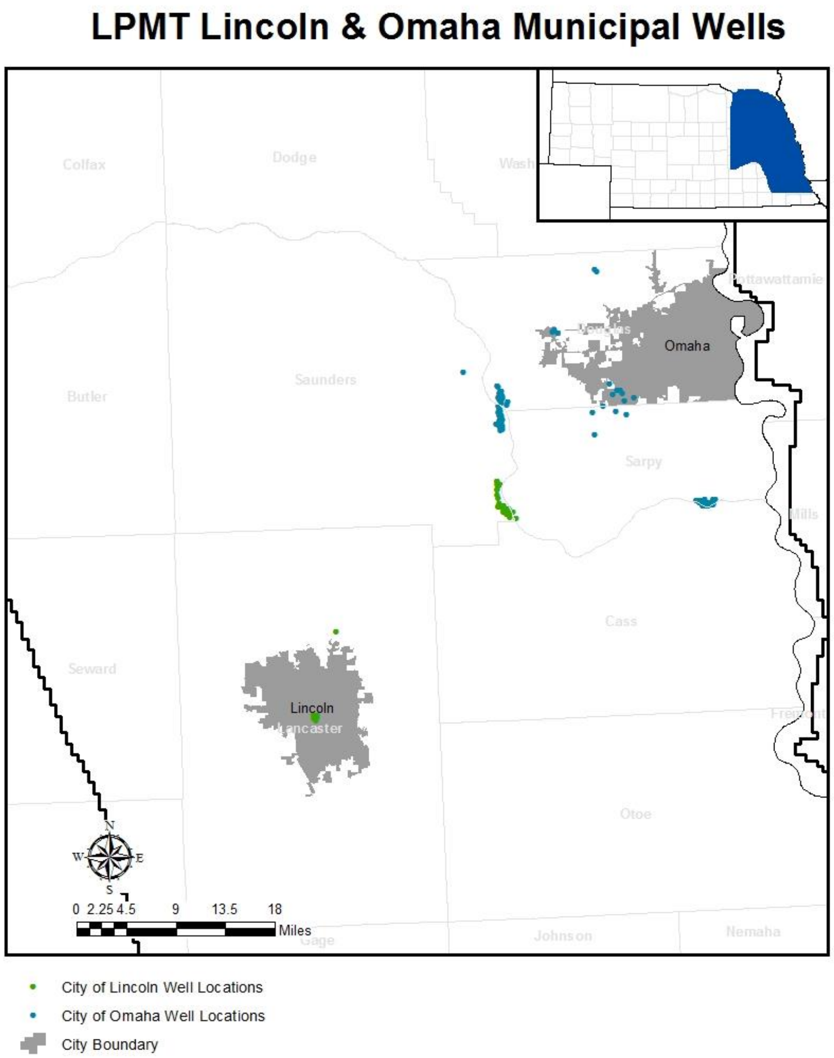

Figure 21. Municipal well for Lincoln and Omaha, Nebraska

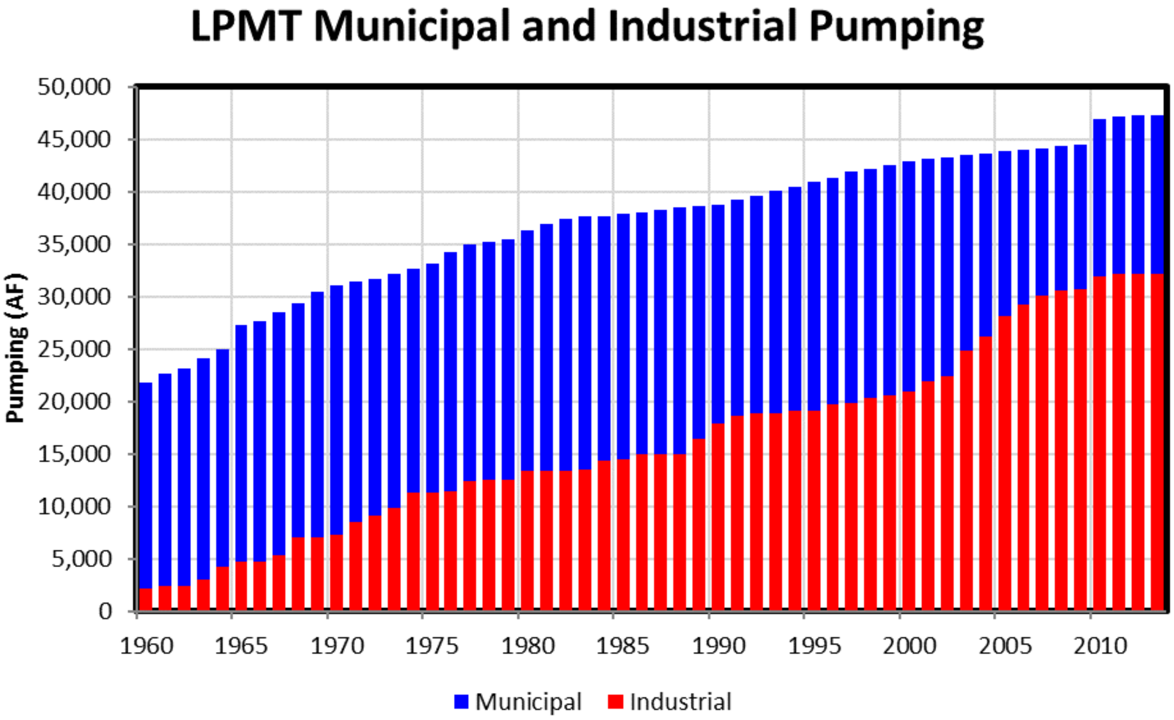

Figure 22. Municipal (sans Omaha and Lincoln) and Industrial pumping in the LPMT model domain.

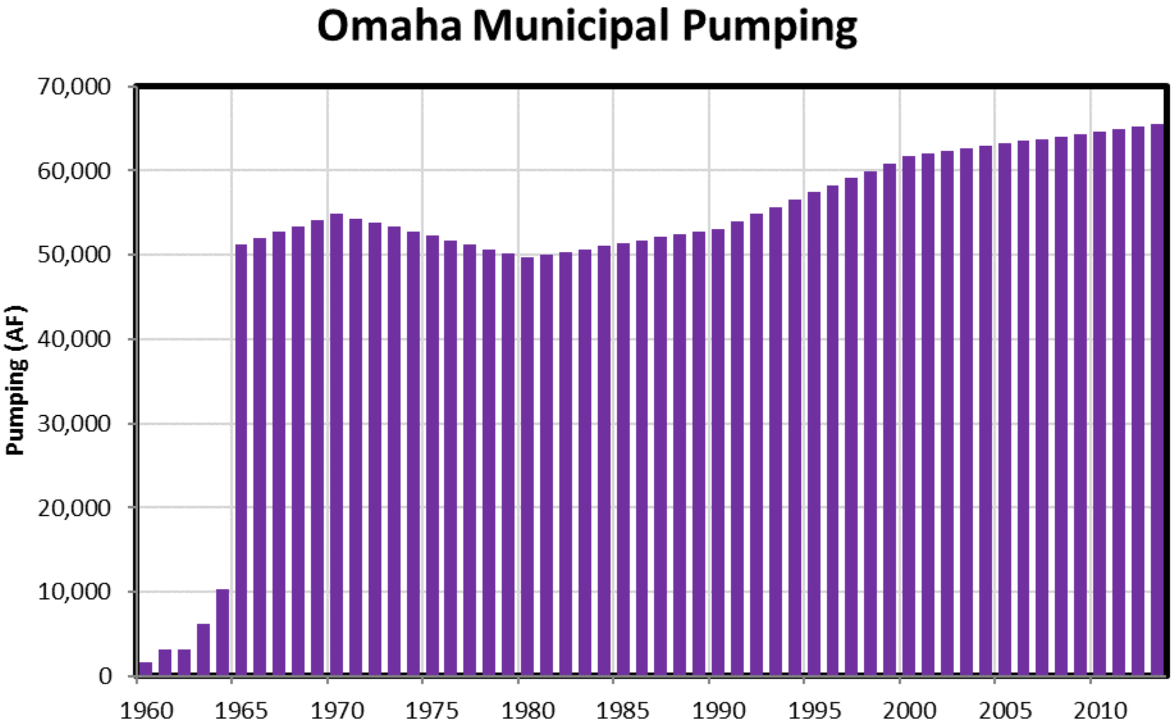

Figure 23. Municipal pumping estimates for the city of Omaha, NE.

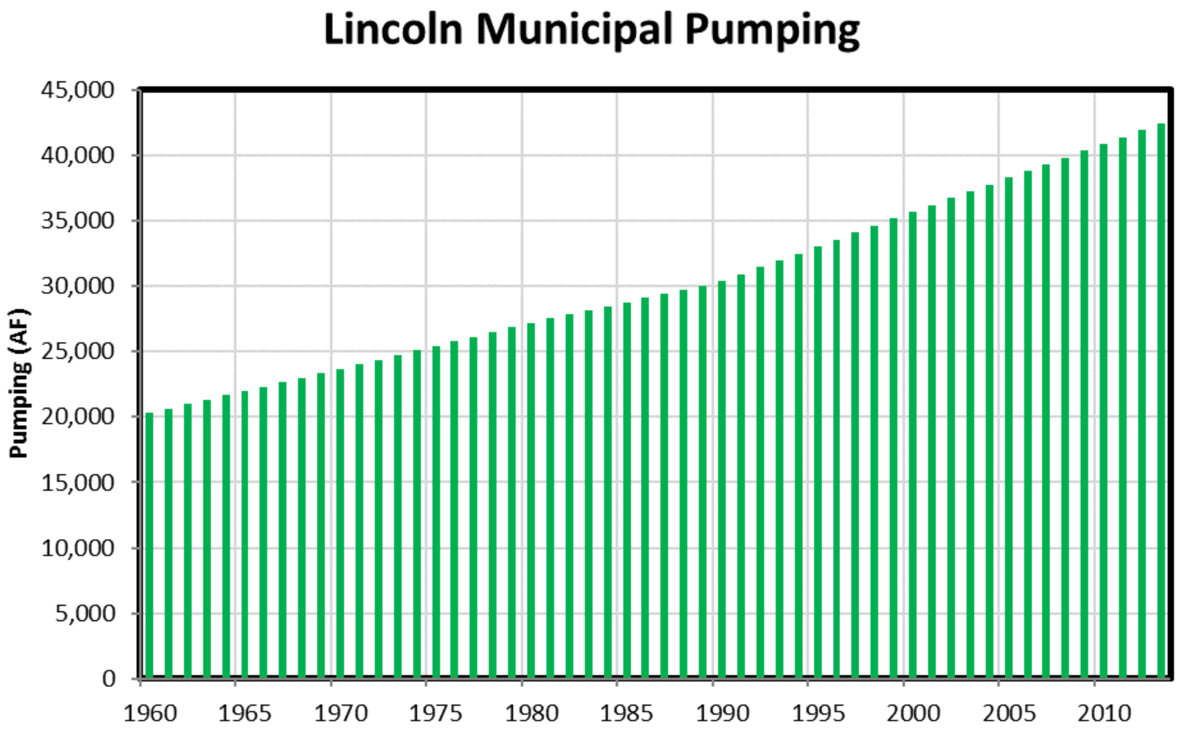

Figure 24. Municipal Pumping estimates for the city of Lincoln, NE.

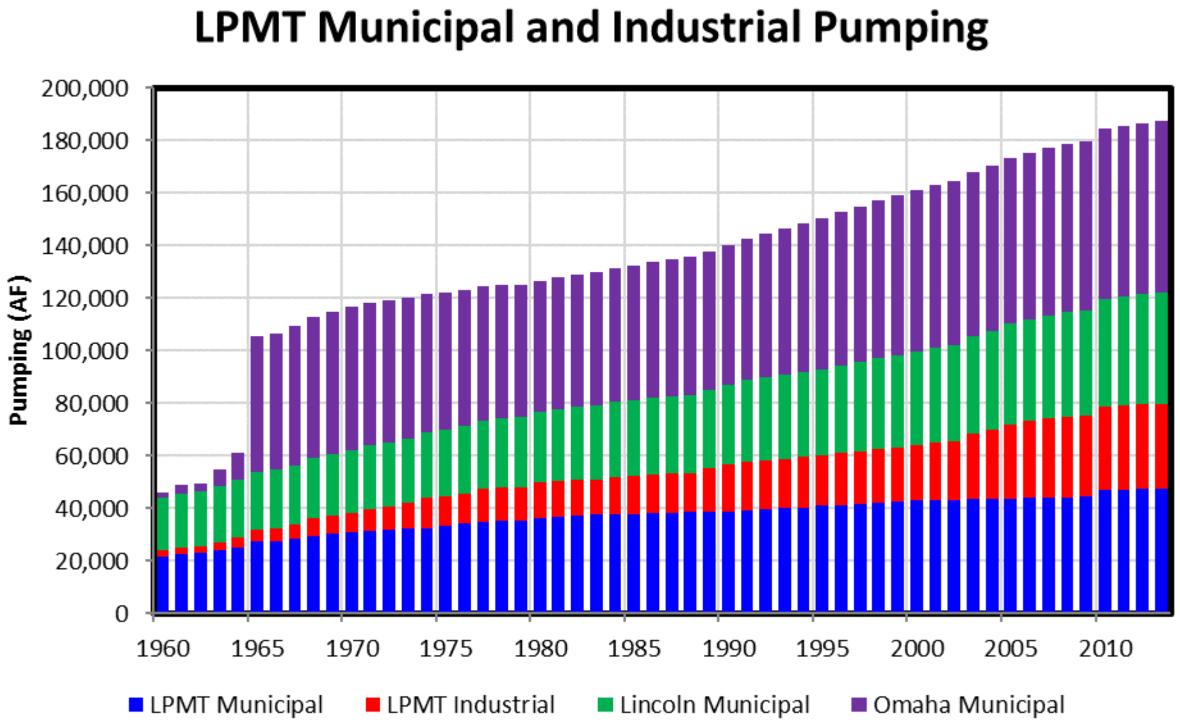

Figure 25. Total Municipal and Industrial pumping in the LPMT model area.

7. Calibration of the RSWB

The goal of the RSWB calibration was to produce a water budget reflecting historical hydrological conditions as accurately as possible. A key measure of the success of this goal was the degree to which the ground water model was able to match field observations of selected water level measurements and streamflow estimates. These ground water model results are largely driven by two primary outputs from the RSWB model:

1. The differences between monthly fluxes into (via recharge) and out of (via pumping) the aquifer. This flux difference is commonly referred to as the net recharge rate.

2. The predicted contribution of overland runoff to streamflow.

Development of these outputs was subject to a number of constraints during calibration.

The overarching constraint during calibration of the RSWB model was the maintaining of an accurate mass balance to ensure appropriate distributions of water throughout the calibration period of 1960-2013. Within the RSWB model, effects from a number of the calibration parameters display dependencies both on one another and upon the magnitude and distribution of related water budget elements. Parameter adjustments must take these dependencies into consideration. Predicted ground water pumping volumes were compared to available ground water pumping meter records which served to constrain estimates of ground water extraction. Baseflow separation estimates were also used during calibration which served to constrain estimates of runoff becoming streamflow.

The overall calibration process was iterative in nature. An initial estimate of pumping and recharge was developed by the RSWB model and provided to the ground water model. Areas where model predicted values deviated from available field observations were investigated and, if justifiable, refinements were made subject to the process constraints. These refined estimates would then be provided back to the ground water model and the process repeated.

Initially adjustments were applied to parameters having the greatest potential impact on either net recharge or runoff and which occurred earliest in the modeling process. Consideration was also given to maintaining consistency with calibration settings within other models bounding the LPMT model area. The majority of the adjustments during calibration were made to seven parameters: the ET adjustment factors ($ADJ_{ET,\ dry}$ & $ADJ_{ET,\ irr}$), the dryland ET partitioning factor (DryET2RO), the runoff transmission losses partitioning factor (%2Rch), and the upper recharge limits (DP_{ll} & DP_{cap}) from the coefficient zone coefficient file; and the loss per mile factor from the runoff zone coefficient file. A complete list of the adjust coefficients can be found in Tables 6 & 8**Error! Reference source not found.** in Appendix A.

Finally, the deep percolation adjustment (ADJ_{DP}) was applied in within coefficient zone 8. A substantial portion of zone 8 consists of the city of Lincoln, NE. The use of the dryland pasture to estimate the water balance parameters was over predicting recharge rates in the area. Considering the permeability of the natural soils compared to the developed land surface, a reduction in experienced infiltration and recharge rates is expected. The deep percolation adjustment was used to accommodate for this difference between the modeled and physical world.

8. Results

The watershed model is capable of producing a wide variety of results on a number of different scales. The following sections will describe a selection these results to provide insight into the watershed model output on global, regional, and local levels. This chapter contains results depicting average conditions, snapshots of a single point in time, and time series values. The results presented in section are from RSWB iteration Run009e, which provided the calibrated recharge and pumping to the groundwater model.

8.1. Global Water Balance

This section presents selected results from the RSWB model. Table 3 provides an overall summary of the key water balance terms represented in the RSWB model. Parameter values are shown both in terms of depth per acre and percent of total applied water (TAW). Depth values shown on the table represent the average volumes divided by the area of the entire model domain, thus depths of applied groundwater (GW) and surface water (SW) are shown as being not applicable (NA). Several terms include the same water at different stages of the modeling process; therefore, the bold terms indicate the water balance parameters which balance. For example, the indirect ET and indirect recharge values reflect the portion of the direct runoff which does not contribute to stream flow. The annual field water balance can be found in Table 4 for the active LPMT model domain; while the annual runoff balance can be found in Table 5.

Table 3. Long term average water balance for the LPMT model domain.

Parameter	Depth (in)	% of TAW
Precipitation	28.36	96.56%
GW Application	NA	3.15%
SW Application	NA	0.29%
Total Applied Water	NA	100.00%
Total ET	23.34	79.45%
Direct ET	22.85	77.70%
Indirect ET	0.49	1.67%
Total Recharge	3.80	12.93%
Direct Recharge	3.34	11.37%
Indirect Recharge	0.46	1.56%
Direct Runoff	3.19	10.86%
Runoff Contributions to Streamflow	2.24	7.63%
Change in Soil Water Content	(0.00)	(0.01)%

Long term averages fell within a range of results from other projects in the model area. Estimated long term average recharge (3.8”) reflect the results show by Szilagyi, 2005 [11] who estimated the mean long term annual recharge in the area varied between 2”-6.5” across the model domain. Furthermore, recharge as percentage of applied water (average 12.9%) was within the range of 9-17% seen across most of the region, with isolated pockets reaching above 20%.

Table 4. Annual Field Water Balance (AF).

Year	Precipitation	Groundwater Pumping	Surface Water Deliveries	Total Applied Water	Direct ET	Direct Recharge	Direct Runoff	Surface Losses	Soil Water Balance
1960	26,493,850	200,101	14,972	26,708,923	20,980,594	3,839,654	2,910,498	4,751	(1,026,574)
1961	23,344,894	330,477	28,484	23,703,855	19,674,686	1,729,761	1,919,906	8,034	371,469
1962	24,505,080	181,102	14,876	24,701,058	20,711,532	2,000,865	2,052,760	4,366	(68,465)
1963	21,168,052	282,158	23,492	21,473,702	19,252,980	1,204,377	1,708,197	6,818	(698,670)
1964	24,994,936	228,578	22,096	25,245,610	20,796,156	1,806,187	2,273,683	5,676	363,907
1965	30,836,674	199,945	15,644	31,052,262	20,999,820	3,826,035	4,095,363	4,781	2,126,263
1966	19,306,044	288,833	25,294	19,620,171	19,728,752	1,175,634	1,302,999	7,041	(2,594,255)
1967	23,156,704	391,267	37,758	23,585,730	18,960,136	2,240,082	3,266,894	9,713	(891,095)
1968	24,609,110	435,534	41,889	25,086,533	18,146,674	1,303,126	1,948,847	10,805	3,677,080
1969	23,221,942	320,705	32,269	23,574,915	20,468,436	2,694,101	1,946,464	8,028	(1,542,112)
1970	21,822,360	585,195	58,869	22,466,424	18,854,826	1,242,226	1,546,016	14,647	808,709
1971	22,960,972	511,358	55,169	23,527,498	19,631,110	2,517,897	2,275,312	12,986	(909,806)
1972	26,285,808	473,903	46,784	26,806,494	20,445,166	2,331,627	2,954,804	11,817	1,063,080
1973	31,014,302	553,809	53,936	31,622,047	21,059,450	5,249,220	4,682,787	13,773	616,817
1974	16,248,651	886,179	89,752	17,224,582	17,866,654	1,463,034	1,412,504	22,211	(3,539,821)
1975	21,922,970	741,284	78,770	22,743,024	19,142,548	892,887	1,693,752	18,764	995,073
1976	15,662,456	1,188,436	122,928	16,973,820	16,726,255	871,603	1,410,439	29,915	(2,064,393)
1977	29,349,204	727,265	80,317	30,156,786	21,651,304	1,953,249	2,884,070	18,561	3,649,602
1978	23,428,820	868,929	77,987	24,375,736	20,090,616	3,137,719	2,673,628	21,278	(1,547,506)
1979	26,249,180	837,565	75,943	27,162,688	20,026,824	2,722,718	2,966,135	20,548	1,426,463
1980	17,685,166	1,195,534	108,500	18,989,200	17,903,368	1,569,443	1,563,194	29,336	(2,076,141)
1981	22,172,536	771,367	70,026	23,013,929	18,706,054	859,890	1,844,782	18,929	1,584,275
1982	31,594,732	558,781	46,923	32,200,436	20,905,464	4,844,618	4,654,386	13,522	1,782,447
1983	26,363,202	1,062,462	98,758	27,524,422	19,498,358	5,573,777	3,382,898	26,187	(956,798)
1984	31,036,308	1,100,507	101,721	32,238,536	20,633,896	6,426,914	5,340,285	27,096	(189,655)

Table 4. Annual Field Water Balance (AF).

Year	Precipitation	Groundwater Pumping	Surface Water Deliveries	Total Applied Water	Direct ET	Direct Recharge	Direct Runoff	Surface Losses	Soil Water Balance
1985	23,898,468	761,116	79,252	24,738,836	20,406,134	2,268,431	2,361,632	19,185	(316,545)
1986	30,674,996	537,450	43,303	31,255,749	22,031,950	4,585,558	3,531,710	12,914	1,093,618
1987	26,743,662	993,595	76,549	27,813,805	20,312,492	4,914,099	3,653,361	23,699	(1,089,846)
1988	17,734,792	1,331,139	131,621	19,197,552	17,933,044	884,739	1,241,236	33,204	(894,671)
1989	17,049,488	1,070,021	97,683	18,217,193	15,992,585	571,759	1,669,389	26,285	(42,825)
1990	21,954,702	889,663	82,691	22,927,056	19,962,316	1,699,116	2,235,100	21,928	(991,404)
1991	24,031,356	1,389,759	131,797	25,552,911	18,843,820	1,955,942	2,551,205	34,385	2,167,560
1992	28,602,306	280,490	27,621	28,910,417	21,209,002	3,731,955	2,966,393	6,991	996,076
1993	33,766,524	181,484	12,120	33,960,128	20,980,688	6,881,285	6,433,619	4,236	(339,699)
1994	23,220,912	539,391	54,674	23,814,977	20,126,094	2,117,852	1,843,881	13,522	(286,372)
1995	24,967,742	1,168,752	114,170	26,250,664	19,707,456	5,070,711	3,035,751	29,084	(1,592,336)
1996	25,761,408	611,169	54,964	26,427,540	19,108,128	2,540,876	3,029,416	14,972	1,734,149
1997	21,741,102	926,592	81,121	22,748,814	19,222,312	2,263,020	1,861,848	22,588	(620,953)
1998	28,902,904	596,962	53,056	29,552,922	20,509,264	4,700,658	3,673,137	14,592	655,271
1999	24,863,030	705,055	58,839	25,626,925	19,470,002	5,173,048	4,077,998	17,043	(3,111,166)
2000	20,241,140	1,251,922	109,019	21,602,081	17,632,402	547,285	1,580,998	30,489	1,810,907
2001	27,037,742	1,001,517	93,817	28,133,076	19,927,276	3,911,601	3,738,712	24,721	530,765
2002	19,025,210	1,324,056	118,804	20,468,070	18,184,162	1,598,588	1,685,656	32,421	(1,032,757)
2003	22,012,750	1,433,419	135,373	23,581,542	19,277,248	1,870,234	2,423,028	35,437	(24,405)
2004	23,686,240	1,164,607	98,654	24,949,501	20,040,594	2,550,719	2,439,343	28,225	(109,380)
2005	23,018,428	1,241,480	115,901	24,375,808	19,289,366	2,541,500	2,397,308	30,625	117,010
2006	24,400,344	1,078,518	97,239	25,576,101	18,941,432	2,085,606	2,122,463	26,432	2,400,168
2007	32,612,358	791,891	73,699	33,477,947	20,885,790	6,511,327	5,735,531	19,523	325,777
2008	29,147,822	1,151,445	94,937	30,394,203	20,603,216	5,875,167	4,396,630	27,776	(508,585)
2009	23,134,932	961,039	75,183	24,171,154	19,951,488	2,501,406	1,736,623	22,980	(41,343)

Table 4. Annual Field Water Balance (AF).

Year	Precipitation	Groundwater Pumping	Surface Water Deliveries	Total Applied Water	Direct ET	Direct Recharge	Direct Runoff	Surface Losses	Soil Water Balance
2010	27,941,234	569,073	43,031	28,553,338	20,388,556	5,437,530	3,868,862	13,533	(1,155,143)
2011	23,784,428	545,143	40,908	24,370,479	19,460,708	3,535,129	2,311,931	12,948	(950,237)
2012	15,541,466	2,369,817	195,821	18,107,104	16,464,323	1,351,341	1,534,194	57,187	(1,299,942)
2013	25,006,760	1,165,705	106,923	26,279,388	19,219,970	1,832,159	3,096,499	28,660	2,102,100

Column Notes:

Groundwater Pumping – the gross volume of water pumped for irrigation.
Surface Water Deliveries – volume of surface water considered applied at the farm head gate.
Total Applied Water – the total volume of precipitation, groundwater pumping and surface water deliveries.
Direct ET – the estimate of ET resulting from the applied water. This does not include ET related to transmission losses.
Direct Recharge – estimate of recharge resulting from the applied water. This does not include recharge from transmission losses.
Direct Runoff – estimate of runoff occurring at the field boundaries.
Surface Losses – evaporative losses related to the application of irrigation to the field.
Field Water Balance – change in soil water moisture content.

Table 5. Annual Runoff Water Balance (AF).

Year	Direct Runoff	Runoff Contributions to Stream Flow	Indirect Recharge	Indirect ET
1960	2,910,498	2,064,193	410,385	435,920
1961	1,919,906	1,307,126	275,828	336,951
1962	2,052,760	1,426,042	304,840	321,878
1963	1,708,197	1,200,215	233,138	274,844
1964	2,273,683	1,627,893	314,208	331,583
1965	4,095,363	2,907,342	544,458	643,564
1966	1,302,999	937,162	185,615	180,222
1967	3,266,894	2,310,311	474,450	482,134
1968	1,948,847	1,342,440	295,890	310,517
1969	1,946,464	1,352,875	283,885	309,704
1970	1,546,016	1,089,698	224,175	232,142
1971	2,275,312	1,620,744	319,384	335,184
1972	2,954,804	2,081,569	431,417	441,819
1973	4,682,787	3,216,743	650,841	815,202
1974	1,412,504	991,323	210,812	210,370
1975	1,693,752	1,192,130	250,112	251,511
1976	1,410,439	975,895	214,016	220,528
1977	2,884,070	2,000,079	421,787	462,203
1978	2,673,628	1,815,111	391,980	466,537
1979	2,966,135	2,060,305	436,585	469,245
1980	1,563,194	1,102,196	219,103	241,895
1981	1,844,782	1,303,048	276,856	264,877
1982	4,654,386	3,281,567	662,624	710,194
1983	3,382,898	2,410,305	479,997	492,596
1984	5,340,285	3,802,953	731,987	805,346
1985	2,361,632	1,654,385	363,537	343,711
1986	3,531,710	2,490,572	480,772	560,366
1987	3,653,361	2,551,126	519,295	582,939
1988	1,241,236	878,607	190,165	172,465
1989	1,669,389	1,160,266	239,807	269,316
1990	2,235,100	1,582,025	330,838	322,237
1991	2,551,205	1,791,571	381,484	378,149
1992	2,966,393	2,057,639	440,185	468,569
1993	6,433,619	4,557,415	843,014	1,033,190
1994	1,843,881	1,304,438	271,539	267,904
1995	3,035,751	2,166,867	451,666	417,218

Table 5. Annual Runoff Water Balance (AF).

Year	Direct Runoff	Runoff Contributions to Stream Flow	Indirect Recharge	Indirect ET
1996	3,029,416	2,093,933	437,535	497,947
1997	1,861,848	1,305,830	270,787	285,232
1998	3,673,137	2,605,213	514,551	553,372
1999	4,077,998	2,856,213	591,051	630,734
2000	1,580,998	1,120,185	234,621	226,192
2001	3,738,712	2,608,849	530,652	599,211
2002	1,685,656	1,189,927	235,272	260,458
2003	2,423,028	1,693,682	364,672	364,674
2004	2,439,343	1,711,816	362,060	365,467
2005	2,397,308	1,680,395	377,183	339,730
2006	2,122,463	1,485,926	312,665	323,872
2007	5,735,531	4,071,946	807,461	856,124
2008	4,396,630	3,098,594	649,385	648,652
2009	1,736,623	1,217,911	257,522	261,190
2010	3,868,862	2,741,482	551,113	576,267
2011	2,311,931	1,619,164	347,950	344,817
2012	1,534,194	1,086,314	218,381	229,499
2013	3,096,499	2,157,431	459,316	479,751

Column Notes:

Direct Runoff – the estimate of runoff occurring at field boundaries.

The remaining terms present the results of further partitioning of the Direct Runoff water:

Indirect Recharge – the volume of transmission loss water resulting in additional recharge.
Indirect ET – the volume of transmission loss water resulting in additional ET.
Runoff Contributions to Stream Flow – the volume of direct runoff which results in stream flow at the gauge.

8.2. Groundwater Pumping

Groundwater pumped for irrigation reflects the extraction of the water from the aquifer for agricultural production. As described in Section 5.1 Equation 2, the pumping rate estimates are a function of the net irrigation requirement, the NIR target, and the application efficiency. Furthermore, these values are developed with considerations for weather, soils, crop, timing of crop water needs, irrigation system, and management characteristics and assumptions.

In 1960 at the onset of the LPMT model simulation period, there was approximately a quarter million acres of groundwater irrigated lands. Over the next 53-year development increased this area to

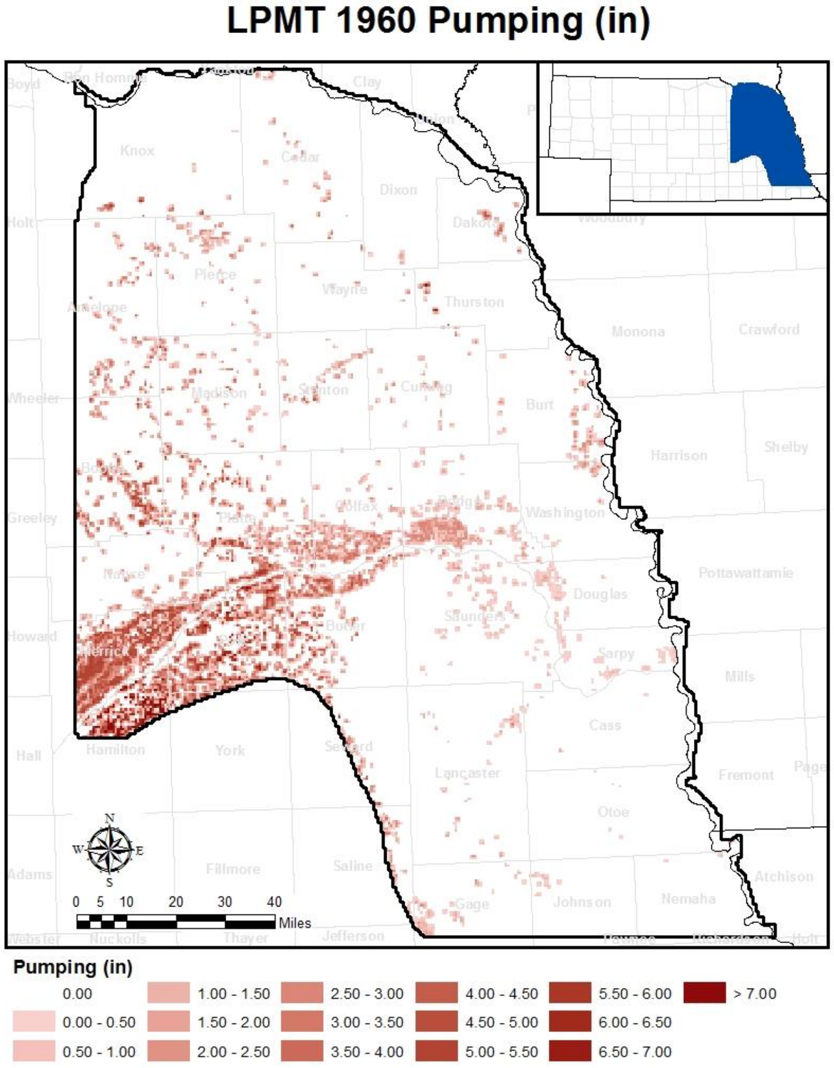

Figure 27. Extent of groundwater pumping in 1960.

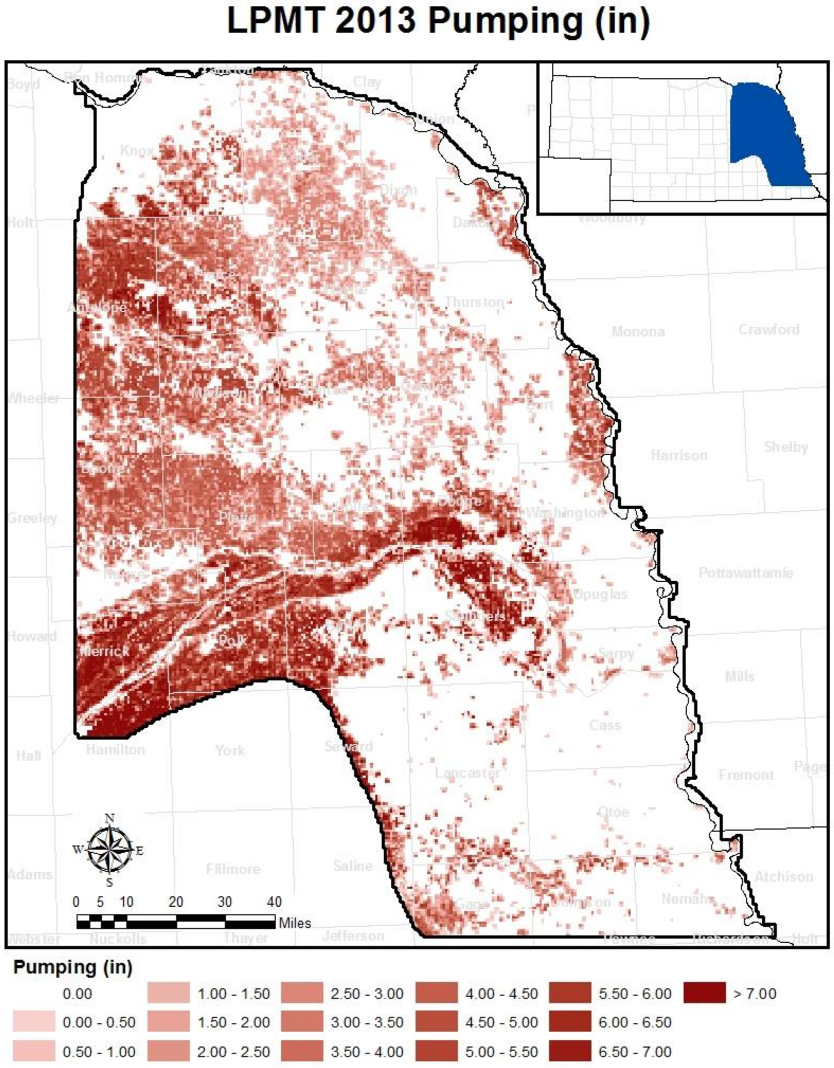

Figure 26. Extent of groundwater pumping in 2013.

approximately 2.1 million acres (Figure 28; Figures 27-26). During this period the average precipitation on groundwater acres was approximately 27.5” and ranged from 16.5” to 38”; while the average pumping was roughly 8.25” and ranged from 1”-15” (Figure 29) with the model wide volumes shown in Figure 30.

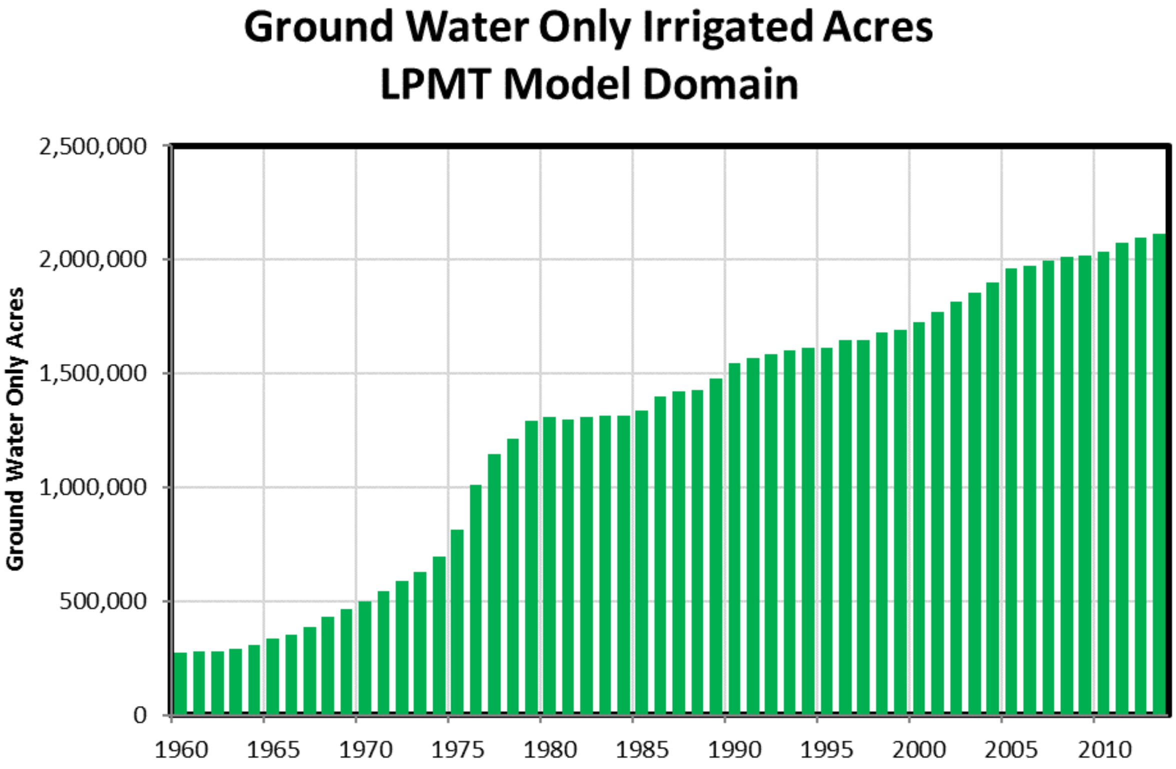

Figure 28. Development of groundwater only acres in the LPMT model domain.

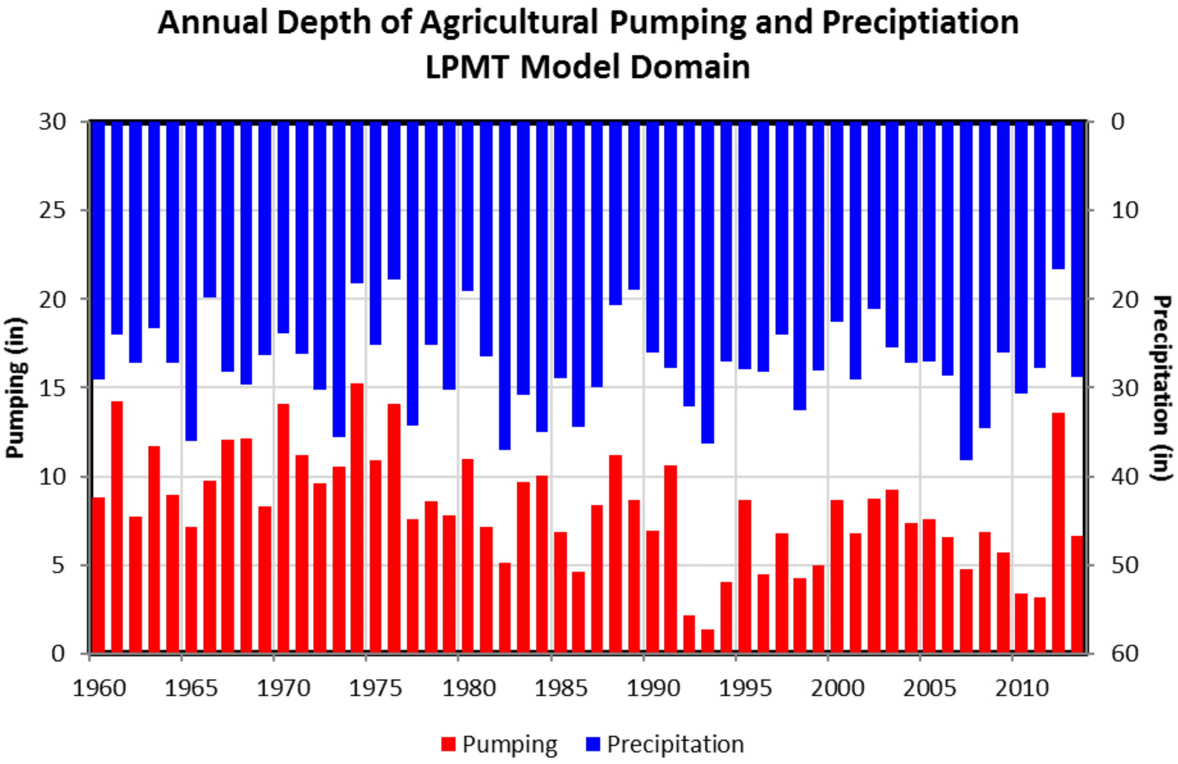

Figure 29. Annual depth of pumping and precipitation in the LPMT model domain.

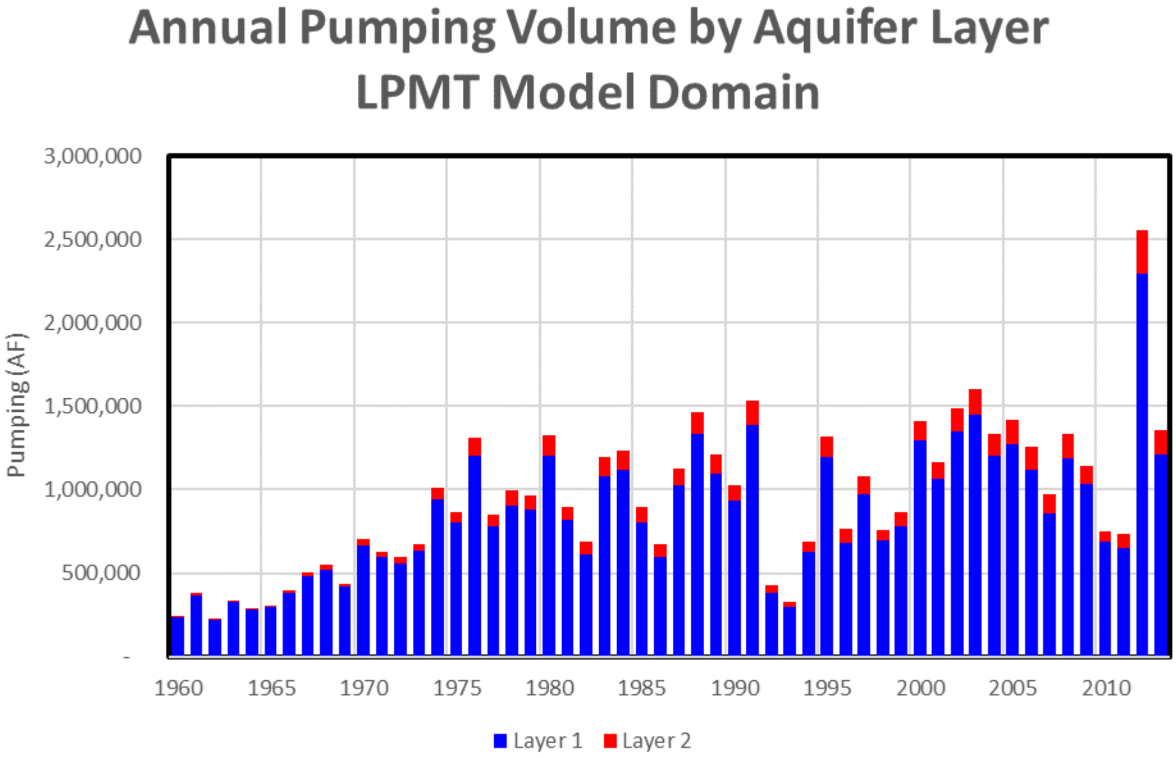

Figure 30. Annual volume of pumping in the LPMT model domain.

Platte County

By 2013, Platte County, with roughly 205,000 acres (Figure 33), has the largest number of groundwater only irrigated acres of any county in the LPMT. Groundwater irrigated lands have developed steadily from the beginning of the simulation period until approximately 2005 when the development leveled off; this pattern of development is reflected in the total estimated pumping volumes. Within Platte County, precipitation ranges between 16”- 39.5” with an average annual value of 27.5”. The corresponding pumping ranged between 0.75” and 15” with an average depth of 8” (Figure 31). The total volume of pumping is shown in Figure 32.

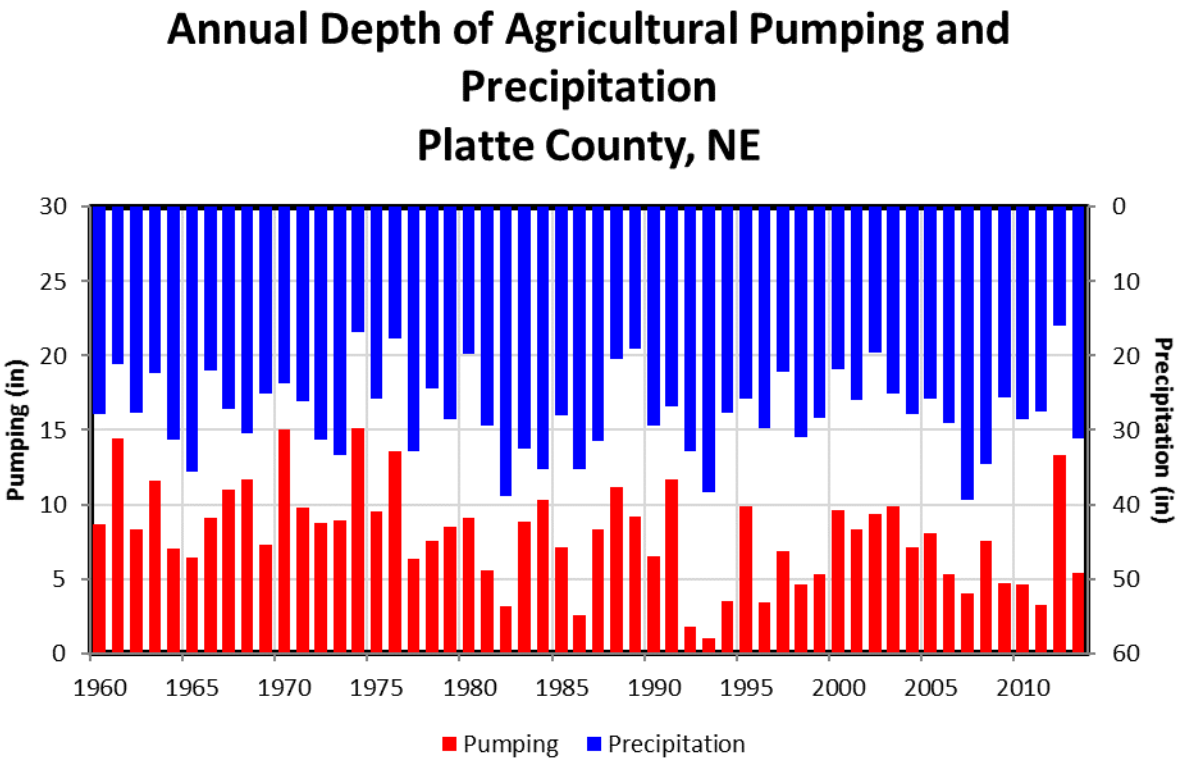

Figure 31. Annual depth of pumping and precipitation in Platte County, NE.

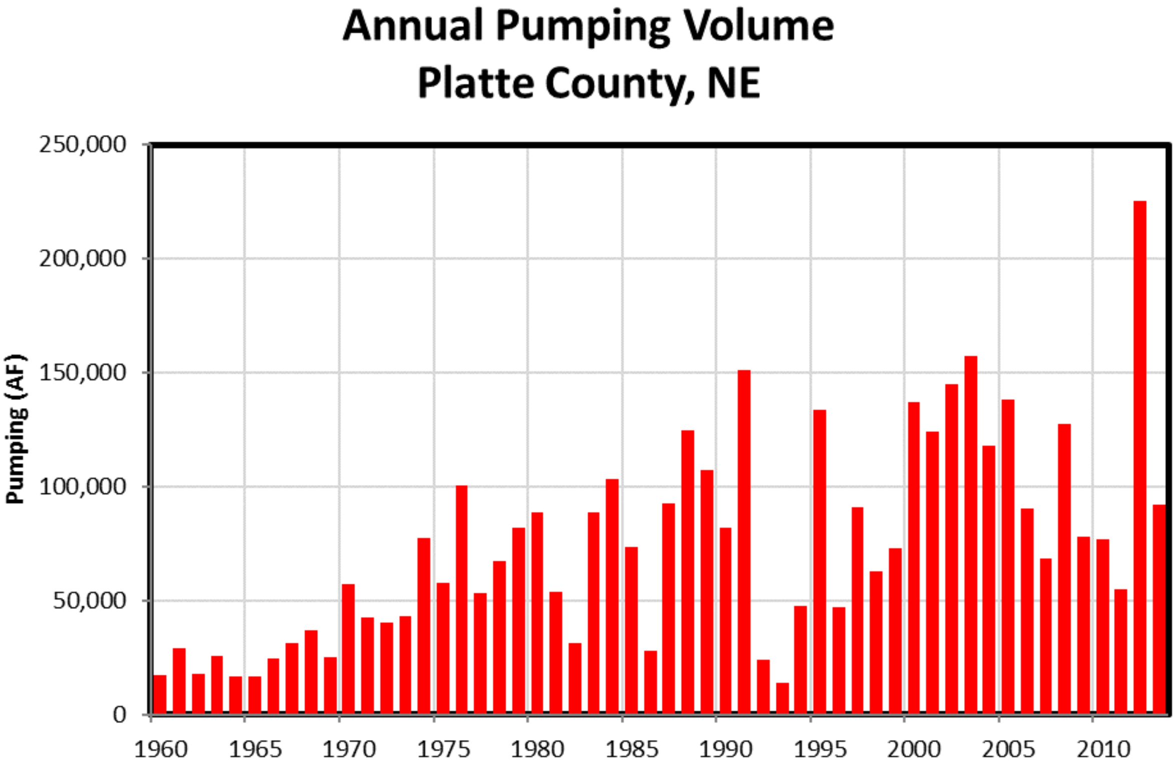

Figure 32. Annual volume of pumping in Platte County, NE

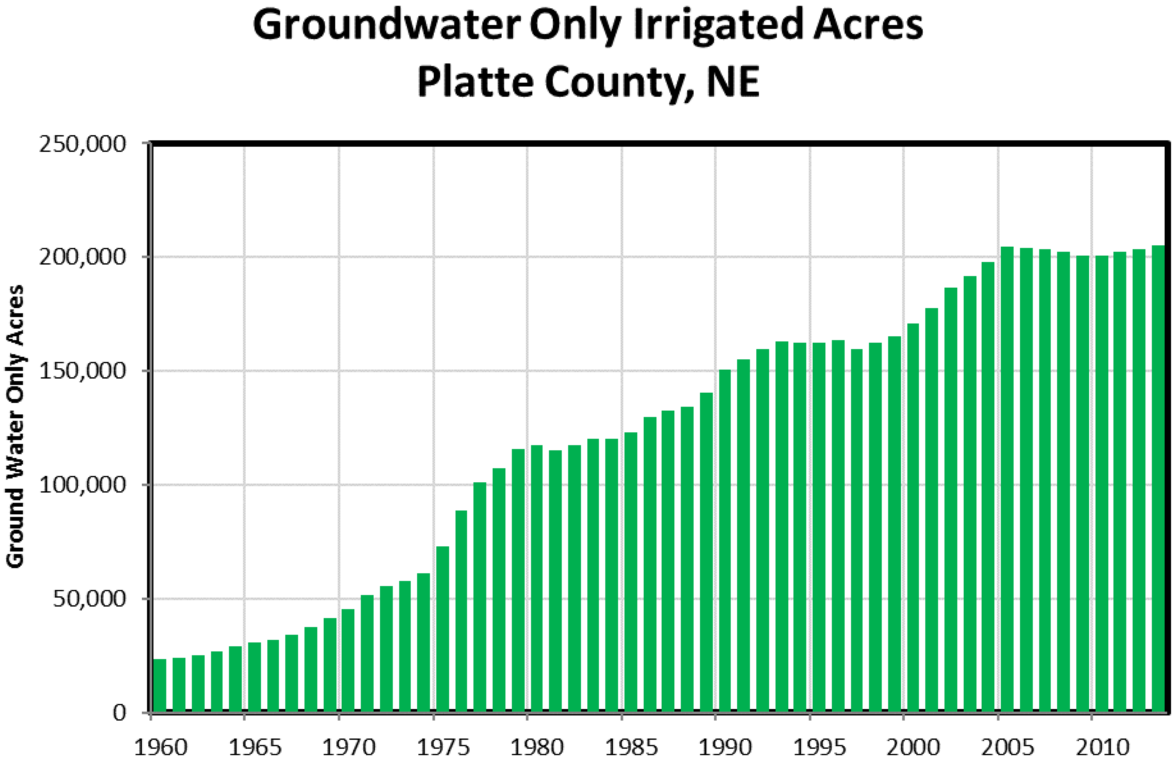

Figure 33. Development of groundwater only acres in Platte County, NE.

Antelope County

As of 2013, Antelope County had the second largest volume of groundwater only irrigated acres of any county in the LPMT model. At the beginning of the simulation period, there were only 5,000 acres. The 1970s saw rapid development of approximately 110,000 acres in the decade. Groundwater only acres steadily increased another 75,000 acres over the next 30 years, for a total development of 190,000 acres[11] (Figure 36). Within Platte County, the precipitation rates varied from 14.5"-39" with an average of 26". This corresponds with average county pumping from between 2"-15", averaging about 8.5" (Figure 34). The total volume of pumping is shown in Figure 35.

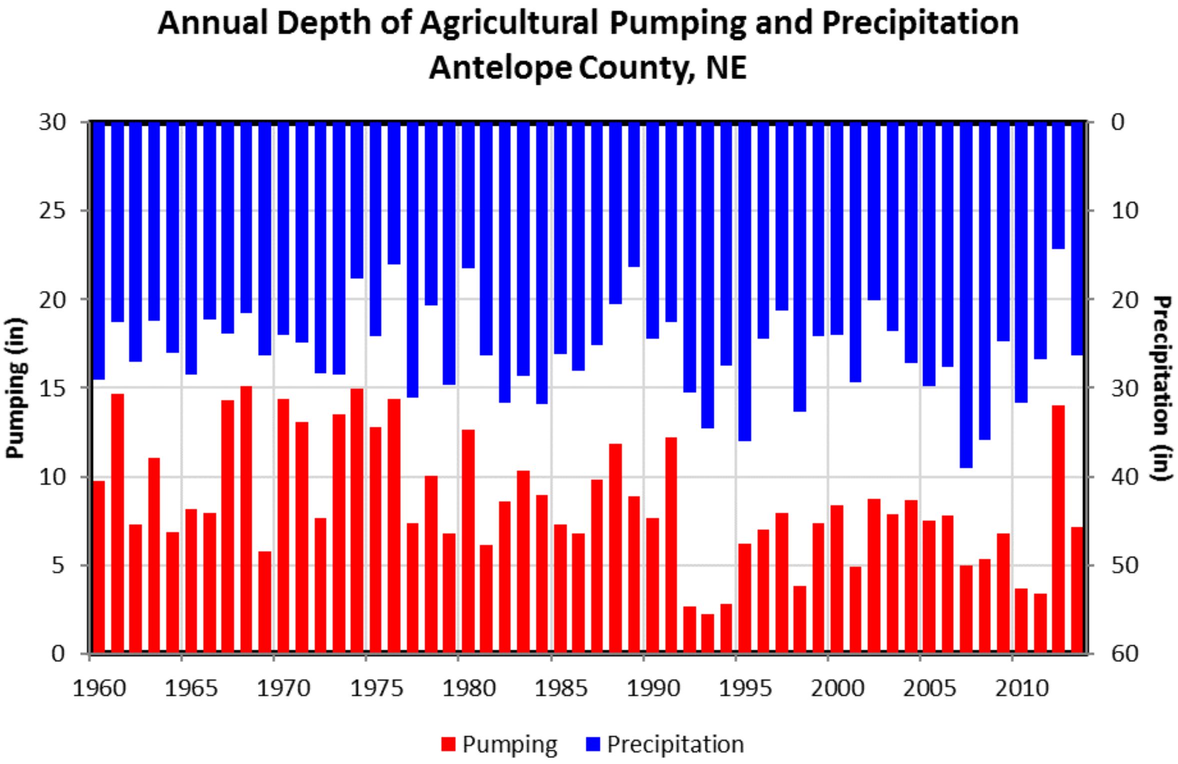

Figure 34. Annual depth of pumping and precipitation in Antelope County, NE

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[11] The acres are limited to the eastern 2/3 of the county which is in the active LPMT model domain.

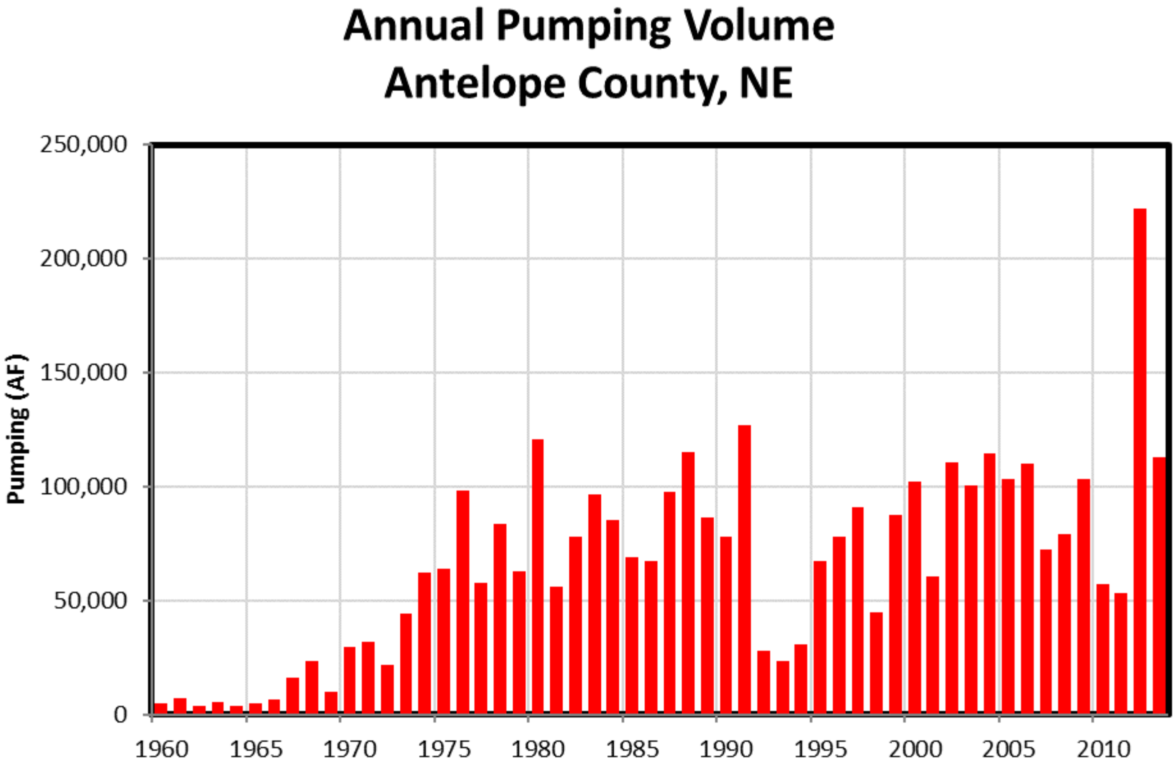

Figure 35. Annual volume of pumping in Antelope County, NE.

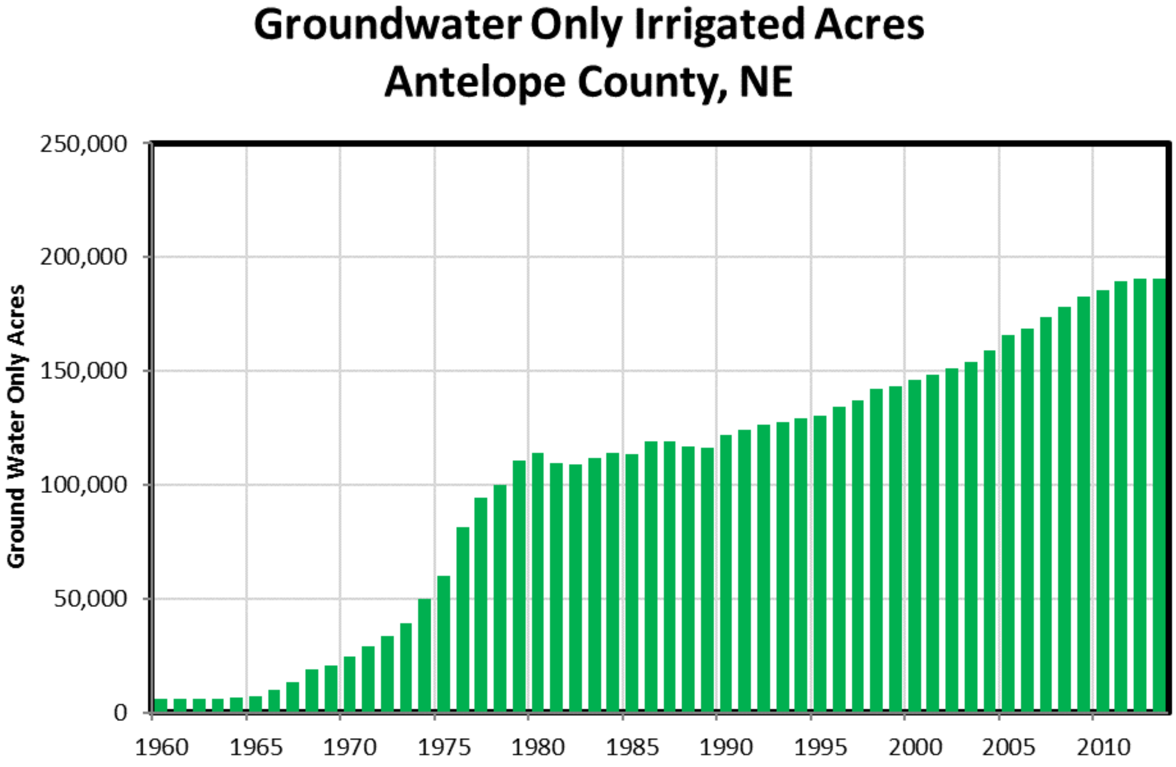

Figure 36. Development of groundwater only acres in Antelope County, NE.

Dixon County

Dixon County contains about 17,000 groundwater only irrigated acres by the end of the model's simulation period. The simulation began with almost no irrigated acres until the mid-1970s. Then there was a 5 year period of rapid development to approximately 15,000 acres. This area remained consistent to the turn of the millennium when additional acres were developed to top out above 21,000 in 2005 (Figure 39). Dixon County averaged 26.5" of precipitation per year with a range of 15"-37". The average county pumping rates ranged from 0"-15.5" with an average of 8" (Figure 37). The total volume of pumping is shown Figure 38.

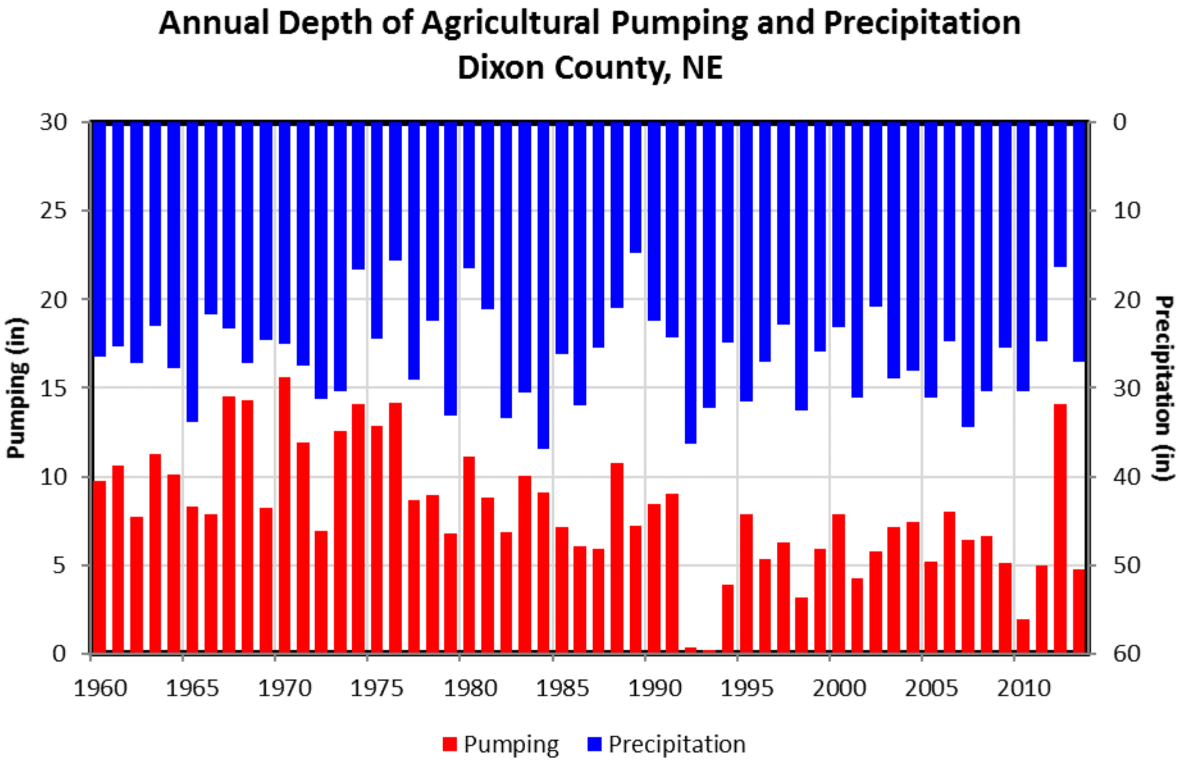

Figure 37. Annual depth of pumping and precipitation in Dixon County, NE.

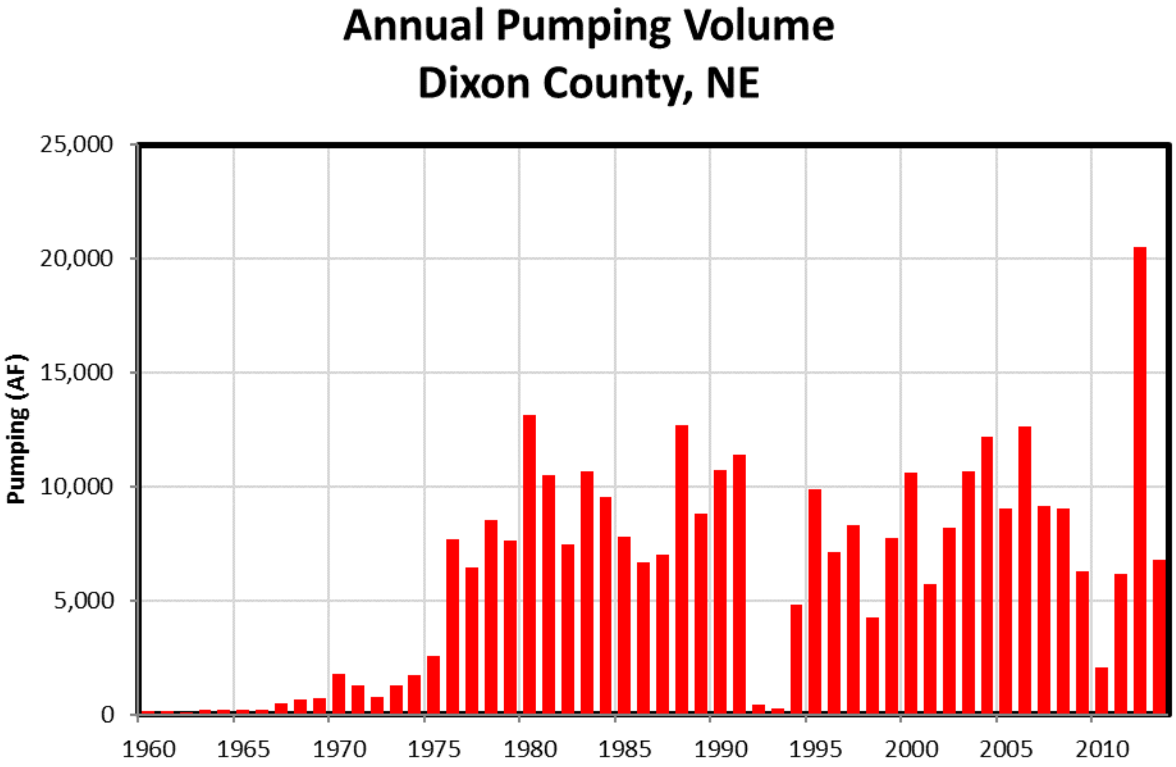

Figure 38. Annual volume of pumping in Dixon County, NE.

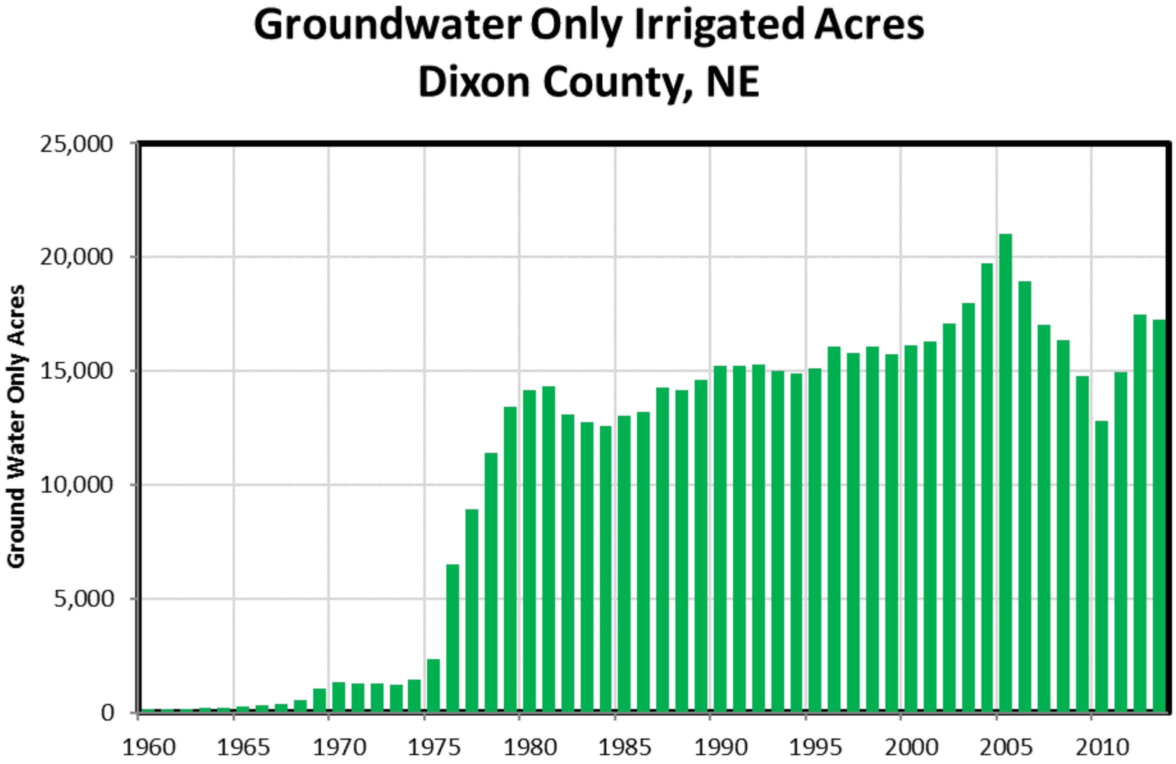

Figure 39. Development of groundwater only acres in Dixon County, NE.

Cass County
Cass County represents an area where the development of groundwater irrigated lands has been minimal. With only 560 acres of groundwater only lands (Figure 42), this county represents the smallest amount in the LPMT model area. Cass County averaged about 31” of precipitation a year with a range between 19” and 53.5”. The county pumping ranged between 0” and 16” with an average of 7.5” (Figure 40). The total volume of pumping is shown Figure 41.

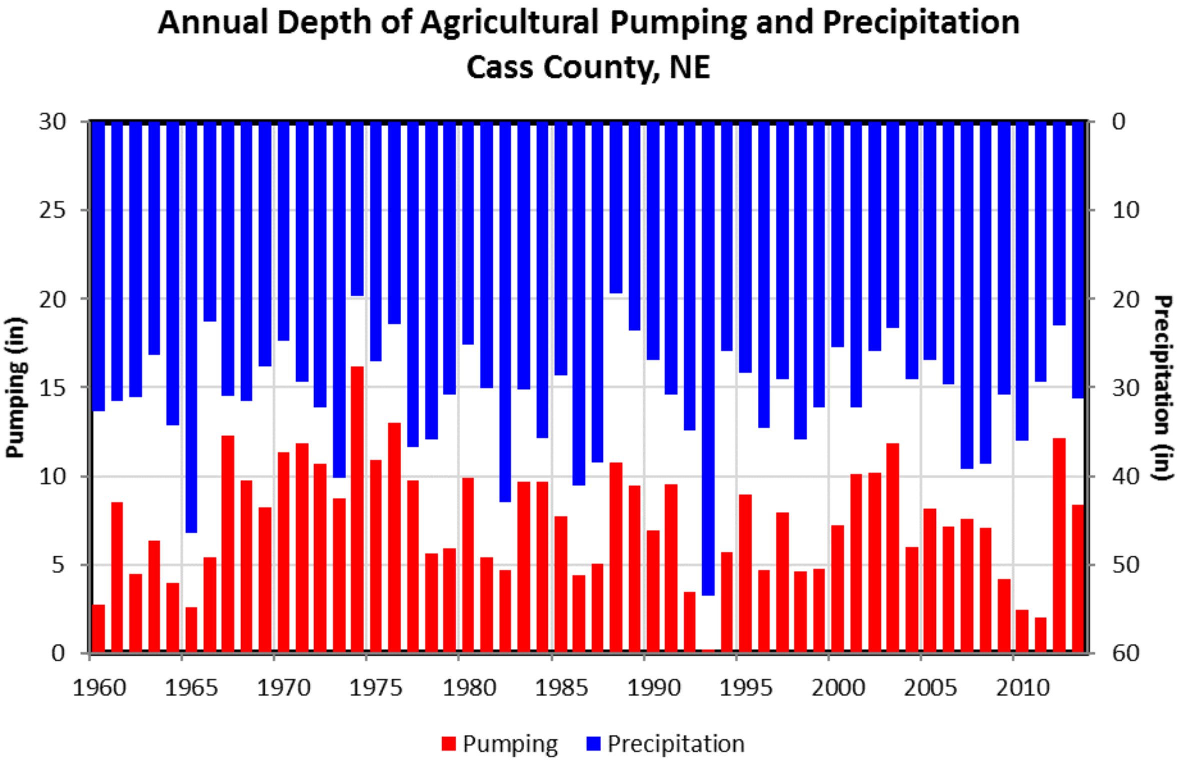

Figure 40. Annual depth of pumping and precipitation in Cass County, NE.

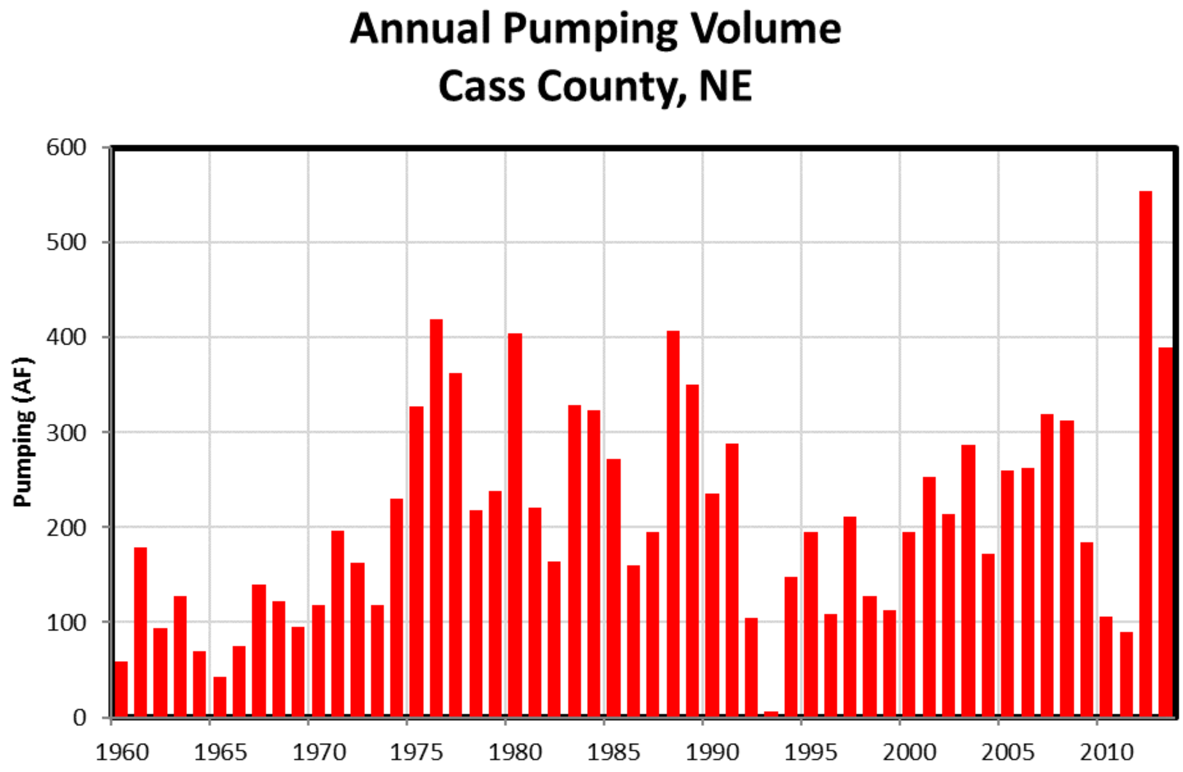

Figure 41. Annual volume of pumping in Cass County, NE.

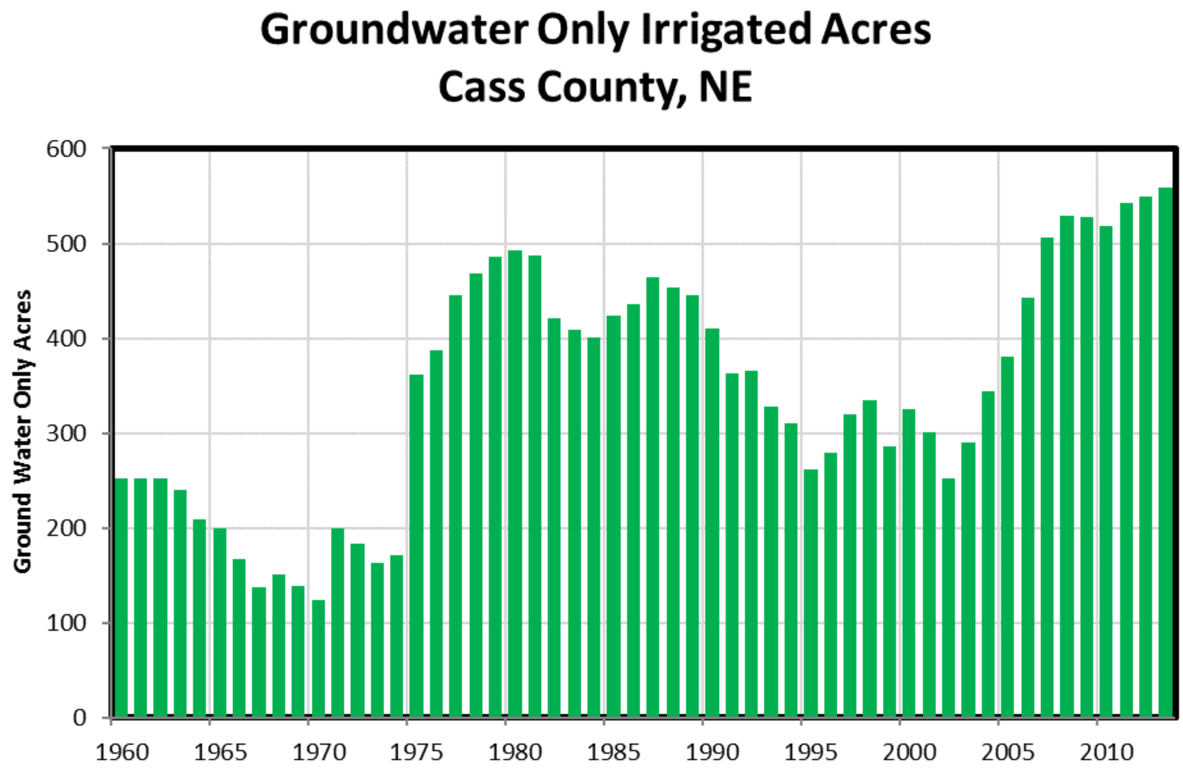

Figure 42. Development of groundwater only acres in Cass County, NE.

The LPMT modeled pumping was compared to the metered pumping collected within the Lower Elkhorn Natural Resources District. Although limited by the sample size (<40 per county per year), the model pumping rate reasonably compares to the metered pumping rate (Figures 43-44).

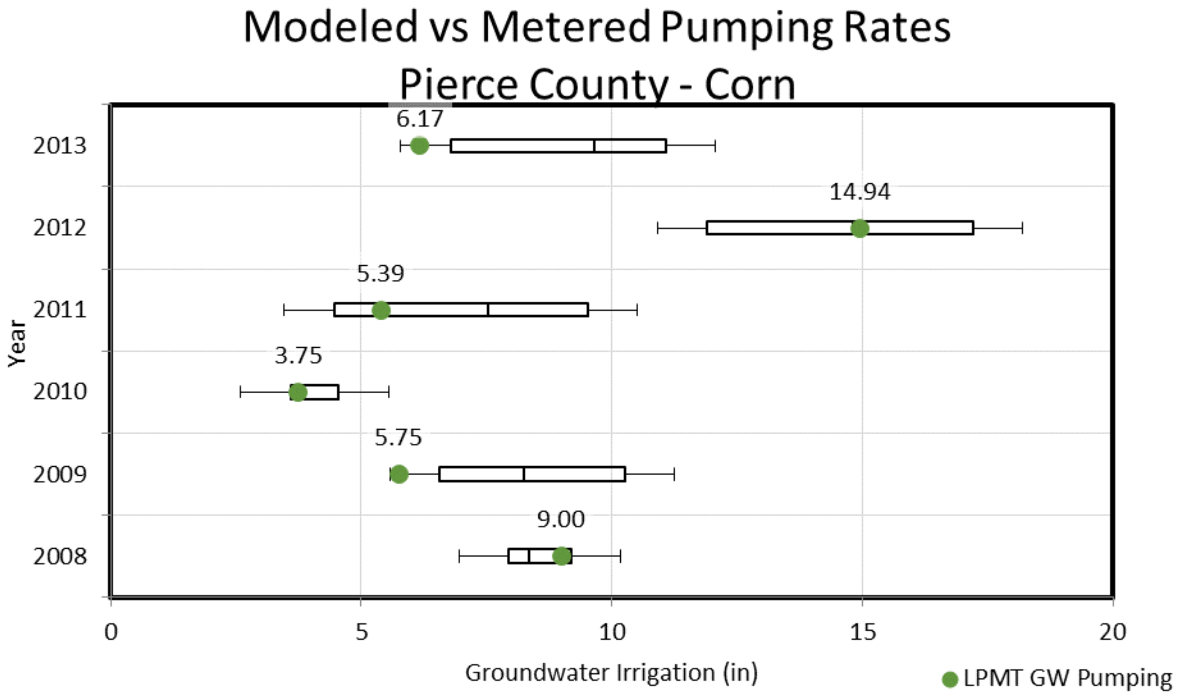

Figure 43. Modeled versus metered Pumping rate on corn in Stanton County

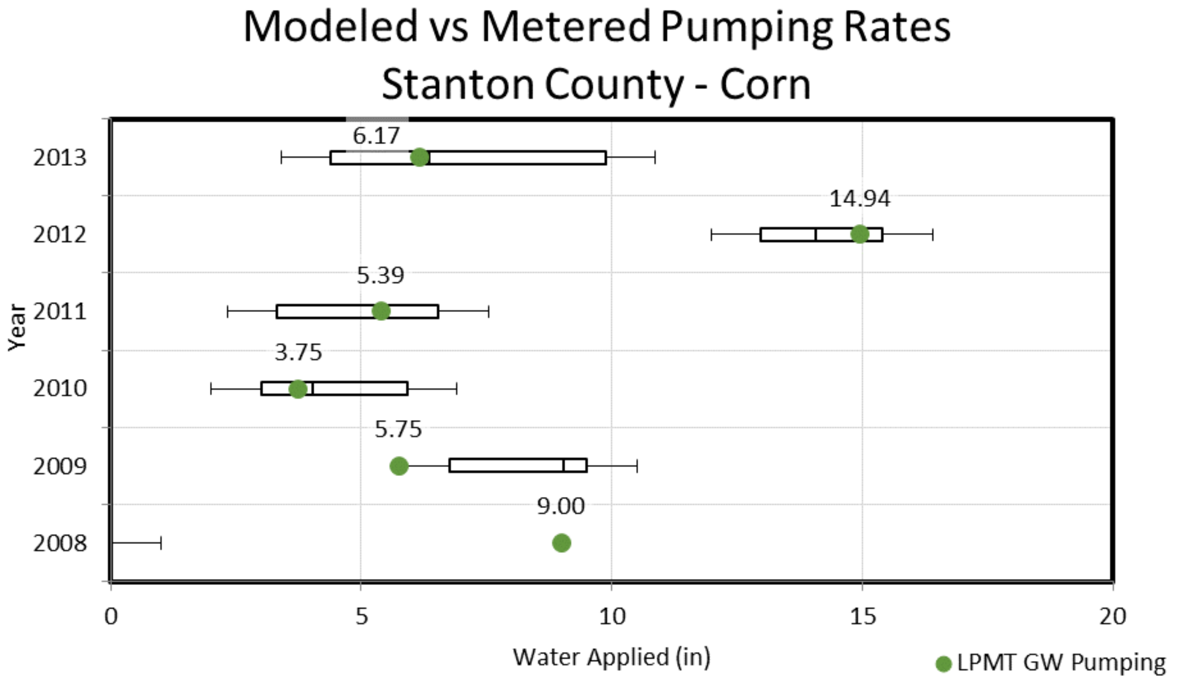

Figure 44. Modeled versus metered Pumping rate on corn in Stanton County

8.3. Recharge

Recharge represents the portion of water which drains past the root zone and reaches the aquifer below. There was approximately 3.80 inches of recharge in the LPMT model domain. Within the LPMT model there are two contributing sources of recharge: direct recharge (3.34”) from the field and indirect recharge (0.46”) resulting from transmission losses from runoff. Figure 46 shows the average annual recharge for the LPMT model area; while Figure 45 depicts the average annual model wide recharge rate for the simulation period. These images show the spatial and temporal variability of the recharge rates and reflect the effect of soils, precipitation, irrigation, soil water content, and timing.

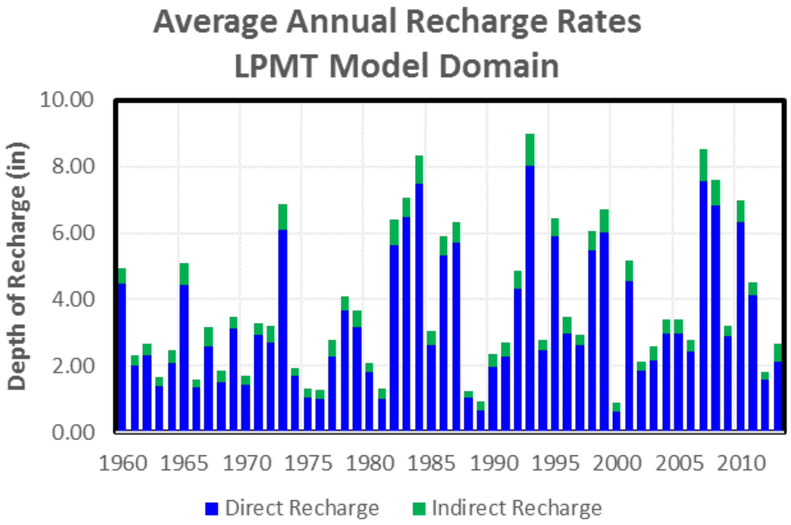

Figure 45. LPMT average annual recharge rates.

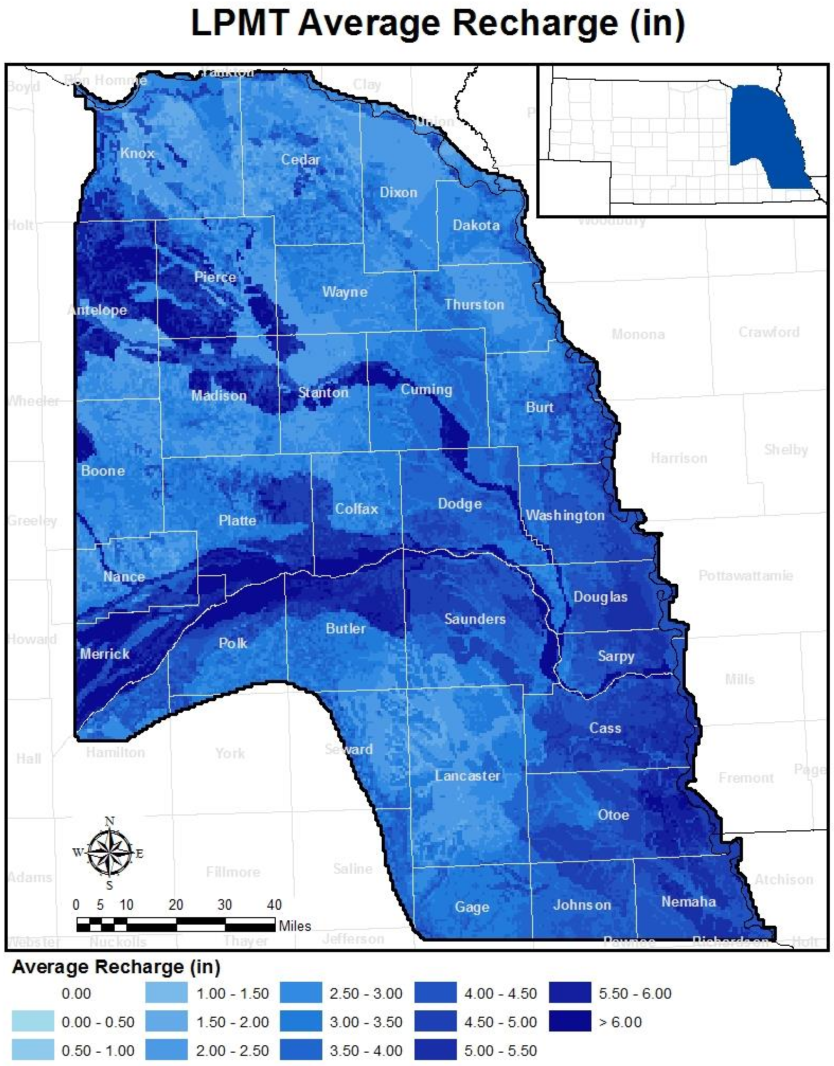

Figure 46. Average annual recharge rates in the LPMT model domain.

8.4. Net Recharge

Net recharge represents the cumulative flux into the aquifer. It considers the recharge to the aquifer (+) and the pumping being extracted (-) which is reflected in Figure 47. On average there was roughly 2.87 inches of net recharge in the LPMT model domain.

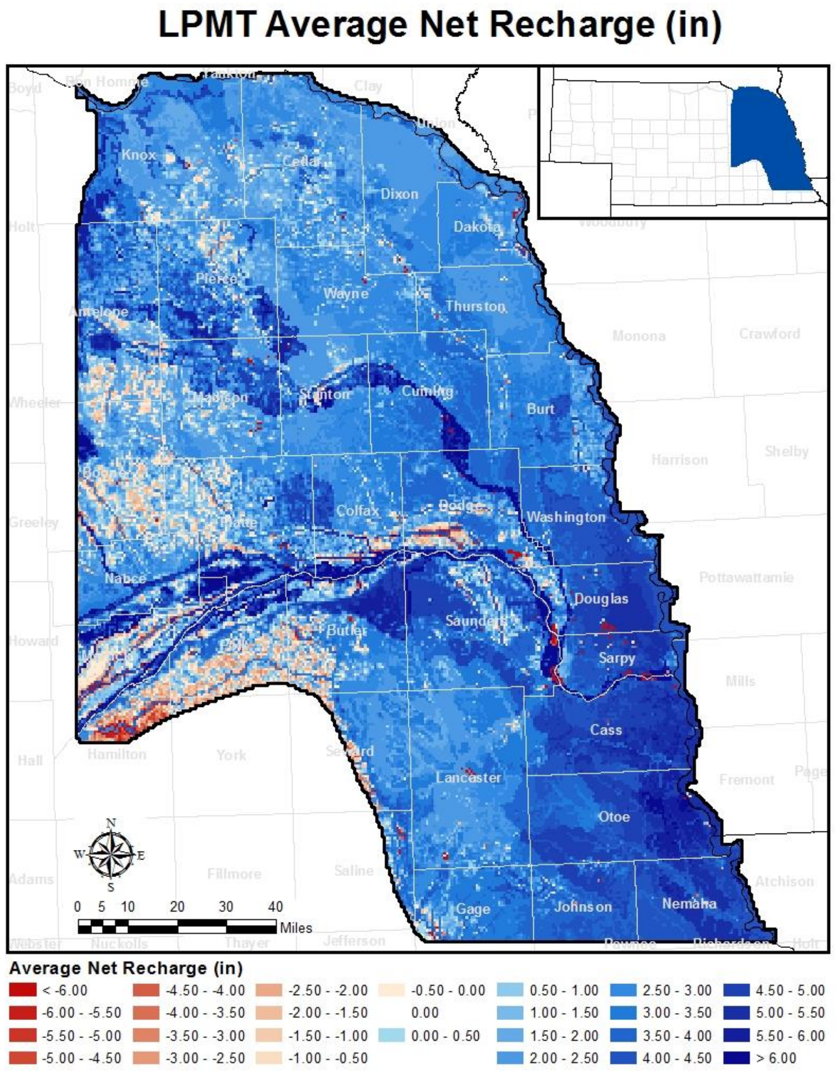

Figure 47. Average net recharge in the LPMT model domain.

8.5. Runoff Contributions to Stream Flow

The runoff contributions to stream flow quantify the portion of the runoff leaving the field which materializes as water in the river at the stream gauge. This estimated contribution is a function of field runoff, distance to the gauge, and characteristics of the watershed. On average the model saw 2.25 inches of runoff become stream flow or roughly 68% of the field runoff. The runoff contributions were then compared to the estimated runoff portion of the gauged flow. This portion was derived using the difference between base flow analysis undertaken for the LPMT model development and the gauged total flow. The following figures show this comparison for the Elkhorn River at West Point (Figure 48), the Elkhorn River at Waterloo (Figure 49), the Salt Creek at Greenwood (Figure 50), the Platte River at Louisville (Figure 51), and the Little Nemaha River at Syracuse (Figure 52).

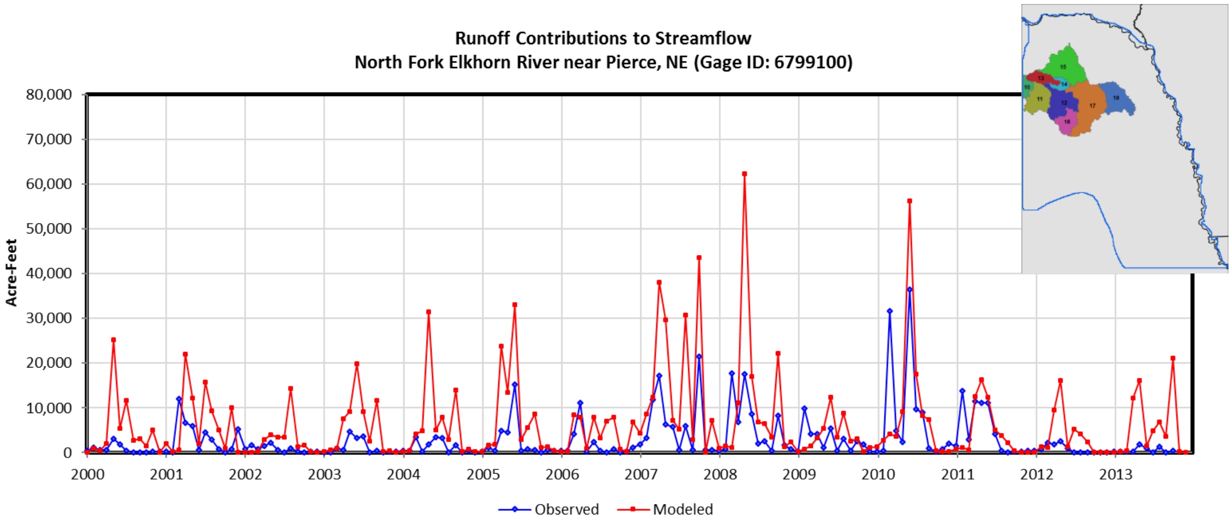

Figure 48. Comparison of the runoff contributions to stream flow for the for the West Point gauge (6799350) on the Elkhorn River. The gauge is located at the end of runoff zone 18 and includes the upstream drainage of zones 10-18.

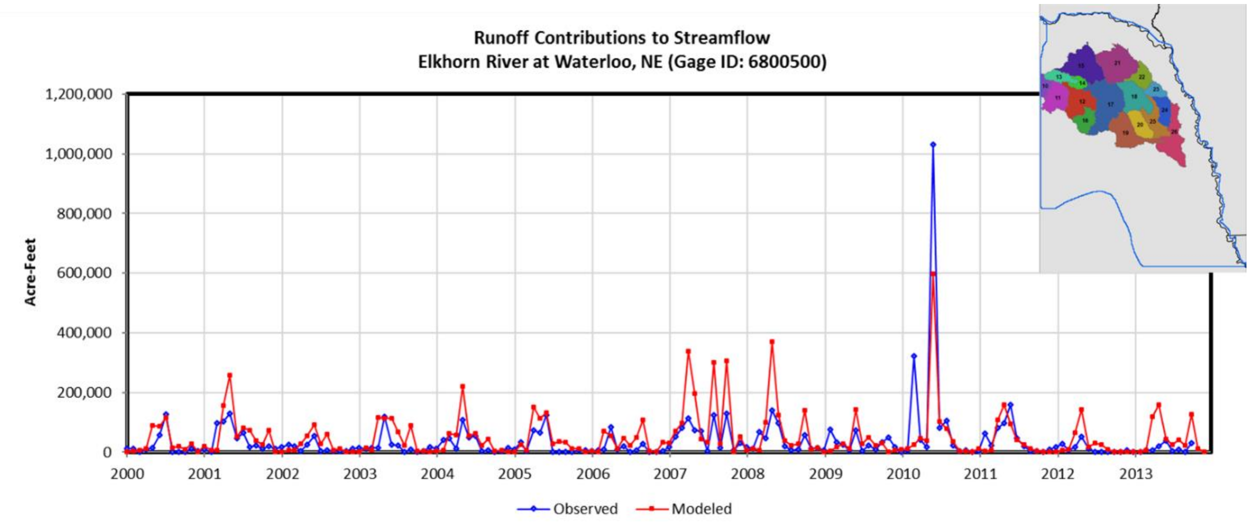

Figure 49. Comparison of the runoff contributions to stream flow for the for the Waterloo gauge (6800500) on the Elkhorn River. The gauge is located at the end of runoff zone 26 and includes the upstream drainage of zones 10-26.

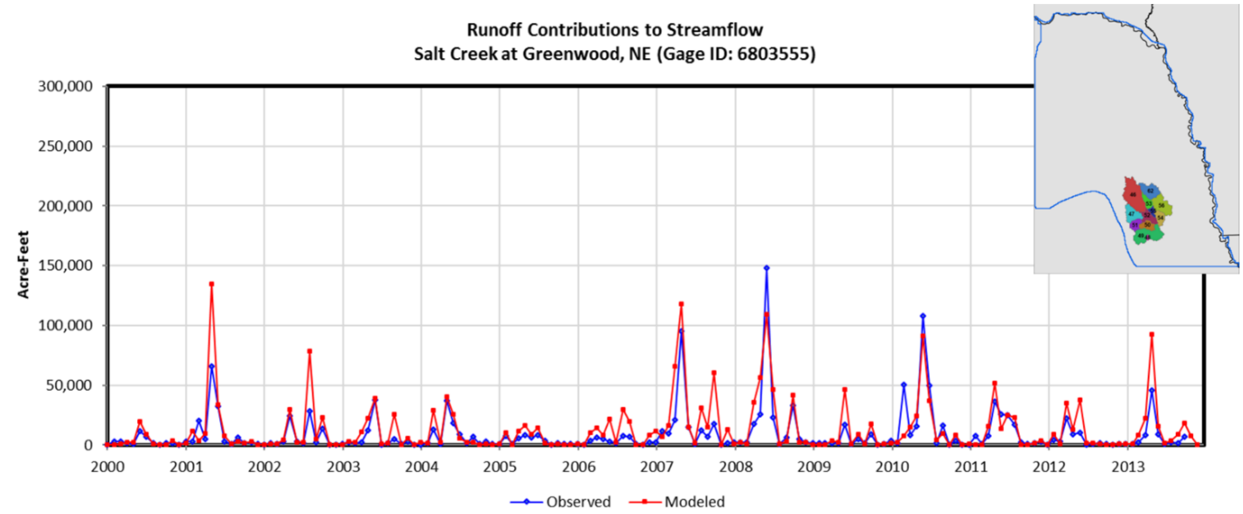

Figure 50. Comparison of the runoff contributions to stream flow for the for the Greenwood gauge (6803555) on the Salt Creek. The gauge is located at the end of runoff zone 56 and includes the upstream drainage of zones 46-56, and 62.

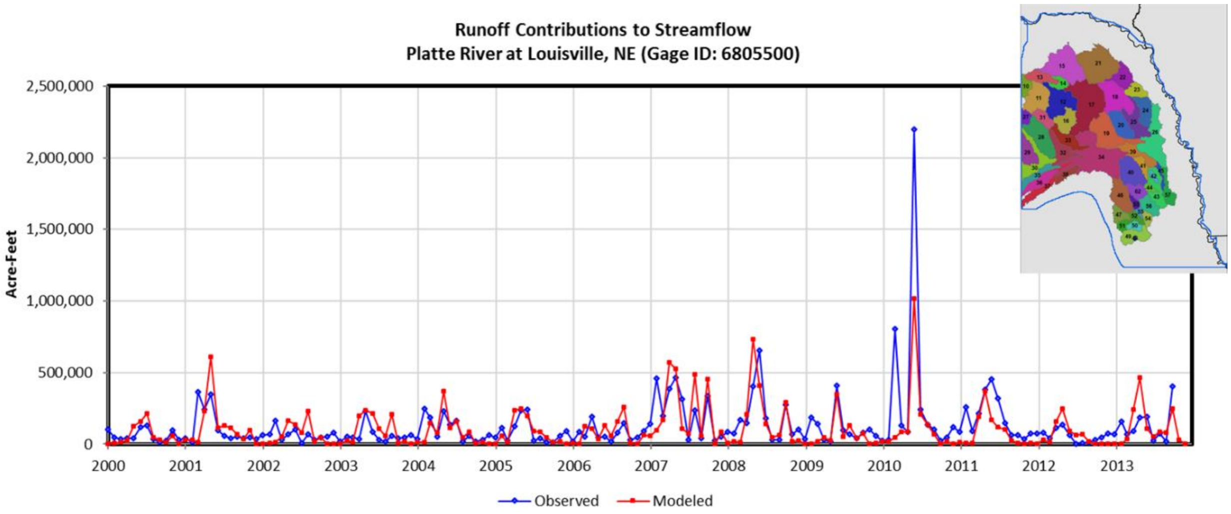

Figure 51. Comparison of the runoff contributions to stream flow for the for the Louisville gauge (6805500) on the Platte River. The gauge is located at the end of runoff zone 57 and includes the upstream drainage of zones 10-57, and 62.

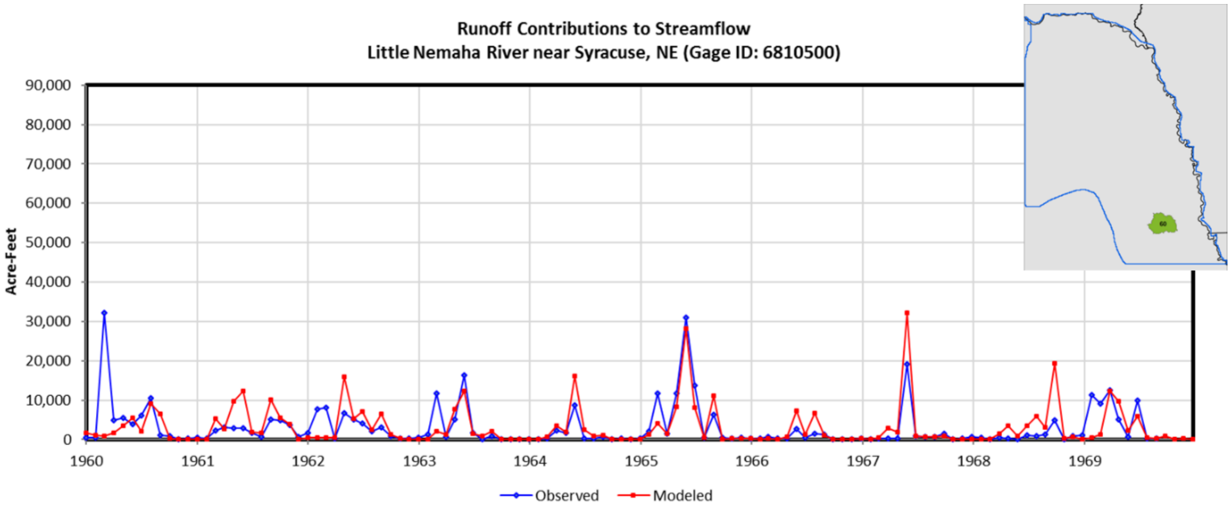

Figure 52. Comparison of the runoff contributions to stream flow for the for the Syracuse gauge (6810500) on the Little Nemaha. The gauge is located at the end of runoff zone 60.

9. References

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Appendix A. Input Tables

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	ADJ$_{ET, Dry}$	ADJ$_{ET, Irr}$	Target $_{NIR}$	ADJ$_{AE, GW}$	FSL$_{GW}$	DryET2RO	ADJ$_{AE, SW}$	FSL$_{SW}$	%2RCH	ADJ$_{DP}$	ADJ$_{RO}$	CM$_{split}$	DP$_{ll}$	DP$_{cap}$	RO$_{f}$DP
1	1	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	2	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	3	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	4	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	5	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	6	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	7	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	8	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	9	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	10	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	11	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	12	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	13	0.955	0.955	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
1	14	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	5.0	10.0	1.0
1	15	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	5.0	10.0	1.0
1	16	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	5.0	10.0	1.0
1	17	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	5.0	10.0	1.0
1	18	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
1	19	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
1	20	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
1	21	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
1	22	0.976	0.976	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
2	1	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	2	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	3	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	4	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	ADJ$_{\text{ET, Dry}}$	ADJ$_{\text{ET, Irr}}$	Target $_{\text{NIR}}$	ADJ$_{\text{AE, GW}}$	FSL$_{\text{GW}}$	DryET2RO	ADJ$_{\text{AE, SW}}$	FSL$_{\text{SW}}$	%2RCH	ADJ$_{\text{DP}}$	ADJ$_{\text{RO}}$	CM$_{\text{split}}$	DP$_{\text{II}}$	DP$_{\text{cap}}$	RO$_{\text{f}}$DP
2	5	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	6	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	7	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	8	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	9	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	10	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	11	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	12	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	13	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	8.0	13.0	1.0
2	14	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	5.0	10.0	1.0
2	15	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	5.0	10.0	1.0
2	16	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	5.0	10.0	1.0
2	17	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	5.0	10.0	1.0
2	18	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
2	19	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
2	20	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
2	21	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
2	22	0.937	0.937	0.85	1.0	0.02	0.400	1.0	0.05	0.650	1.00	1.00	1.0	4.0	8.0	1.0
3	1	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	2	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	3	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	4	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	5	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	6	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	7	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	8	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	9	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	$ADJ_{ET, Dry}$	$ADJ_{ET, Irr}$	Target $_{NIR}$	$ADJ_{AE, GW}$	FSL_{GW}	DryET2RO	$ADJ_{AE, SW}$	FSL_{SW}	%2RCH	ADJ_{DP}	ADJ_{RO}	CM_{split}	DP_{ll}	DP_{cap}	$RO_{f}DP$
3	10	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	11	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	12	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	13	0.965	0.965	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	8.0	13.0	1.0
3	14	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
3	15	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
3	16	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
3	17	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
3	18	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
3	19	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
3	20	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
3	21	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
3	22	0.970	0.970	0.85	1.0	0.02	0.678	1.0	0.05	0.337	1.00	1.00	1.0	5.0	10.0	1.0
4	1	0.920	0.920	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	12.0	15.0	1.0
4	2	0.920	0.920	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	12.0	15.0	1.0
4	3	0.920	0.920	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	12.0	15.0	1.0
4	4	0.920	0.920	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	5	0.920	0.920	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	6	0.920	0.920	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	7	0.920	0.920	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	8	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	9	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	10	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	11	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	12	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	13	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	8.0	13.0	1.0
4	14	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	7.0	12.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	$ADJ_{ET, Dry}$	$ADJ_{ET, Irr}$	Target $_{NIR}$	$ADJ_{AE, GW}$	FSL_{GW}	DryET2RO	$ADJ_{AE, SW}$	FSL_{SW}	%2RCH	ADJ_{DP}	ADJ_{RO}	CM_{split}	DP_{ll}	DP_{cap}	RO_fDP
4	15	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	7.0	12.0	1.0
4	16	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	7.0	12.0	1.0
4	17	0.940	0.940	0.85	1.0	0.02	0.333	1.0	0.05	0.667	1.00	1.00	1.0	7.0	12.0	1.0
4	18	0.970	0.970	0.85	1.0	0.02	0.633	1.0	0.05	0.482	1.00	1.00	1.0	7.0	12.0	1.0
4	19	0.970	0.970	0.85	1.0	0.02	0.633	1.0	0.05	0.482	1.00	1.00	1.0	7.0	12.0	1.0
4	20	0.970	0.970	0.85	1.0	0.02	0.633	1.0	0.05	0.482	1.00	1.00	1.0	7.0	12.0	1.0
4	21	0.970	0.970	0.85	1.0	0.02	0.633	1.0	0.05	0.482	1.00	1.00	1.0	7.0	12.0	1.0
4	22	0.970	0.970	0.85	1.0	0.02	0.633	1.0	0.05	0.482	1.00	1.00	1.0	7.0	12.0	1.0
5	1	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	12.0	15.0	1.0
5	2	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	12.0	15.0	1.0
5	3	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	12.0	15.0	1.0
5	4	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	5	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	6	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	7	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	8	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	9	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	10	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	11	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	12	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	13	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	10.0	15.0	1.0
5	14	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0
5	15	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0
5	16	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0
5	17	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0
5	18	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0
5	19	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	ADJ$_{\text{ET, Dry}}$	ADJ$_{\text{ET, Irr}}$	Target $_{\text{NIR}}$	ADJ$_{\text{AE, GW}}$	FSL$_{\text{GW}}$	DryET2RO	ADJ$_{\text{AE, SW}}$	FSL$_{\text{SW}}$	%2RCH	ADJ$_{\text{DP}}$	ADJ$_{\text{RO}}$	CM$_{\text{split}}$	DP$_{\text{ll}}$	DP$_{\text{cap}}$	RO$_{\text{f}}$DP
5	20	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0
5	21	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0
5	22	0.920	0.920	0.85	1.0	0.02	0.200	1.0	0.05	0.800	1.00	1.00	1.0	8.0	13.0	1.0
6	1	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	2	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	3	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	4	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	5	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	6	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	7	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	8	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	9	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	10	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	11	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	12	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	13	0.945	0.945	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	10.0	15.0	1.0
6	14	0.970	0.970	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
6	15	0.970	0.970	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
6	16	0.970	0.970	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
6	17	0.970	0.970	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
6	18	0.975	0.975	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
6	19	0.975	0.975	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
6	20	0.975	0.975	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
6	21	0.975	0.975	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
6	22	0.975	0.975	0.85	1.0	0.02	0.750	1.0	0.05	0.250	1.00	1.00	1.0	7.0	12.0	1.0
7	1	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	2	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	ADJ$_{ET, Dry}$	ADJ$_{ET, Irr}$	Target $_{NIR}$	ADJ$_{AE, GW}$	FSL$_{GW}$	DryET2RO	ADJ$_{AE, SW}$	FSL$_{SW}$	%2RCH	ADJ$_{DP}$	ADJ$_{RO}$	CM$_{split}$	DP$_{ll}$	DP$_{cap}$	RO$_f$DP
7	3	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	4	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	5	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	6	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	7	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	8	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	9	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	10	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	11	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	12	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	13	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.700	1.00	1.00	1.0	10.0	15.0	1.0
7	14	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
7	15	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
7	16	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
7	17	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
7	18	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
7	19	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
7	20	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
7	21	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
7	22	0.950	0.950	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
8	1	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	2	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	3	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	4	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	5	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	6	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	7	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	$ADJ_{ET, Dry}$	$ADJ_{ET, Irr}$	Target $_{NIR}$	$ADJ_{AE, GW}$	FSL_{GW}	DryET2RO	$ADJ_{AE, SW}$	FSL_{SW}	%2RCH	ADJ_{DP}	ADJ_{RO}	CM_{split}	DP_{ll}	DP_{cap}	$RO_{f}DP$
8	8	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	9	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	10	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	11	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	12	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	13	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	1.00	1.00	1.0	8.0	13.0	1.0
8	14	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
8	15	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
8	16	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
8	17	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
8	18	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
8	19	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
8	20	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
8	21	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
8	22	0.998	0.998	0.85	1.0	0.02	0.800	1.0	0.05	0.200	0.97	1.00	1.0	4.0	8.0	1.0
9	1	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	2	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	3	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	4	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	5	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	6	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	7	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	8	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	9	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	10	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	11	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
9	12	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	$ADJ_{ET, Dry}$	$ADJ_{ET, Irr}$	$Target_{NIR}$	$ADJ_{AE, GW}$	FSL_{GW}	DryET2RO	$ADJ_{AE, SW}$	FSL_{SW}	%2RCH	ADJ_{DP}	ADJ_{RO}	CM_{split}	DP_{ll}	DP_{cap}	RO_fDP
9	13	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
9	14	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
9	15	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
9	16	0.975	0.975	0.85	1.0	0.02	0.650	1.0	0.05	0.650	1.00	1.00	1.0	7.0	12.0	1.0
9	17	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
9	18	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
9	19	0.975	0.975	0.85	1.0	0.02	0.650	1.0	0.05	0.650	1.00	1.00	1.0	7.0	12.0	1.0
9	20	0.975	0.975	0.85	1.0	0.02	0.650	1.0	0.05	0.650	1.00	1.00	1.0	7.0	12.0	1.0
9	21	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
9	22	0.975	0.975	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	7.0	12.0	1.0
10	1	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	2	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	3	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	4	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	5	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	6	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	7	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	8	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	9	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	10	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	11	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	12	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	13	0.930	0.930	0.85	1.0	0.02	0.250	1.0	0.05	0.745	1.00	1.00	1.0	10.0	15.0	1.0
10	14	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	7.0	12.0	1.0
10	15	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	7.0	12.0	1.0
10	16	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	7.0	12.0	1.0
10	17	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	7.0	12.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	$ADJ_{ET, Dry}$	$ADJ_{ET, Irr}$	Target $_{NIR}$	$ADJ_{AE, GW}$	FSL_{GW}	DryET2RO	$ADJ_{AE, SW}$	FSL_{SW}	%2RCH	ADJ_{DP}	ADJ_{RO}	CM_{split}	DP_{ll}	DP_{cap}	RO_fDP
10	18	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	5.0	10.0	1.0
10	19	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	5.0	10.0	1.0
10	20	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	5.0	10.0	1.0
10	21	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	5.0	10.0	1.0
10	22	0.960	0.960	0.85	1.0	0.02	0.500	1.0	0.05	0.745	1.00	1.00	1.0	5.0	10.0	1.0
11	1	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	2	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	3	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	4	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	5	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	6	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	7	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	8	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	9	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	10	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	11	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	12	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	13	0.985	0.985	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	8.0	13.0	1.0
11	14	0.990	0.990	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	5.0	10.0	1.0
11	15	0.990	0.990	0.85	1.0	0.02	0.500	1.0	0.05	0.500	1.00	1.00	1.0	5.0	10.0	1.0
11	16	0.990	0.990	0.85	1.0	0.02	0.650	1.0	0.05	0.500	1.00	1.00	1.0	5.0	10.0	1.0
11	17	0.990	0.990	0.85	1.0	0.02	0.650	1.0	0.05	0.500	1.00	1.00	1.0	5.0	10.0	1.0
11	18	0.990	0.990	0.85	1.0	0.02	0.650	1.0	0.05	0.500	1.00	1.00	1.0	5.0	10.0	1.0
11	19	0.990	0.990	0.85	1.0	0.02	0.650	1.0	0.05	0.500	1.00	1.00	1.0	5.0	10.0	1.0
11	20	0.990	0.990	0.85	1.0	0.02	0.650	1.0	0.05	0.500	1.00	1.00	1.0	5.0	10.0	1.0
11	21	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.200	1.00	1.00	1.0	5.0	10.0	1.0
11	22	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.200	1.00	1.00	1.0	5.0	10.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	ADJ$_{ET, Dry}$	ADJ$_{ET, Irr}$	Target $_{NIR}$	ADJ$_{AE, GW}$	FSL$_{GW}$	DryET2RO	ADJ$_{AE, SW}$	FSL$_{SW}$	%2RCH	ADJ$_{DP}$	ADJ$_{RO}$	CM$_{split}$	DP$_{ll}$	DP$_{cap}$	RO$_{f}$DP
12	1	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	2	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	3	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	4	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	5	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	6	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	7	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	8	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	9	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	10	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	11	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	12	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	13	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	8.0	13.0	1.0
12	14	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
12	15	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
12	16	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
12	17	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
12	18	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
12	19	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
12	20	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
12	21	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
12	22	0.990	0.990	0.85	1.0	0.02	0.654	1.0	0.05	0.321	1.00	1.00	1.0	5.0	10.0	1.0
13	1	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	2	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	3	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	4	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	5	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	ADJ$_{\text{ET, Dry}}$	ADJ$_{\text{ET, Irr}}$	Target $_{\text{NIR}}$	ADJ$_{\text{AE, GW}}$	FSL$_{\text{GW}}$	DryET2RO	ADJ$_{\text{AE, SW}}$	FSL$_{\text{SW}}$	%2RCH	ADJ$_{\text{DP}}$	ADJ$_{\text{RO}}$	CM$_{\text{split}}$	DP$_{\text{ll}}$	DP$_{\text{cap}}$	RO$_{\text{f}}$DP
13	6	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	7	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	8	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	9	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	10	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	11	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	12	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	13	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	8.0	13.0	1.0
13	14	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
13	15	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
13	16	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
13	17	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
13	18	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
13	19	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
13	20	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
13	21	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
13	22	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	5.0	10.0	1.0
14	1	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	2	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	3	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	4	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	5	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	6	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	7	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	8	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	9	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	10	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0

Table 6. Adjustment coefficients from the Coefficient File.

Zone	Soil	$ADJ_{ET,\ Dry}$	$ADJ_{ET,\ Irr}$	$Target_{NIR}$	$ADJ_{AE,\ GW}$	FSL_{GW}	DryET2RO	$ADJ_{AE,\ SW}$	FSL_{SW}	%2RCH	ADJ_{DP}	ADJ_{RO}	CM_{split}	DP_{ll}	DP_{cap}	$RO_{f}DP$
14	11	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	12	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	13	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	10.0	15.0	1.0
14	14	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	7.0	12.0	1.0
14	15	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	7.0	12.0	1.0
14	16	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	7.0	12.0	1.0
14	17	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	7.0	12.0	1.0
14	18	0.998	0.998	0.85	1.0	0.02	0.750	1.0	0.05	0.300	1.00	1.00	1.0	7.0	12.0	1.0
14	19	0.950	0.950	0.85	1.0	0.02	0.300	1.0	0.05	0.700	1.00	1.00	1.0	7.0	12.0	1.0
14	20	0.950	0.950	0.85	1.0	0.02	0.300	1.0	0.05	0.700	1.00	1.00	1.0	7.0	12.0	1.0
14	21	0.950	0.950	0.85	1.0	0.02	0.300	1.0	0.05	0.700	1.00	1.00	1.0	7.0	12.0	1.0
14	22	0.950	0.950	0.85	1.0	0.02	0.300	1.0	0.05	0.700	1.00	1.00	1.0	7.0	12.0	1.0

Column Notes:

Zone references the Coefficient Zone

Soil indicates the CROPSIM soil class index defined in

The columns match the descriptions found in Model Regions (Section 6.10)

Table 7. CROPSIM Soil Class Index

Index	Soil	Index	Soil	Index	Soil	Index	Soil
1	412	7	522	13	642	18	822
2	421	8	612	14	721	19	831
3	431	9	621	15	722	20	832
4	442	10	622	16	731	21	921
5	512	11	631	17	732	22	922
6	521	12	632				

Table 8. Runoff Zone Coefficients – Loss per mile (%)

	Soils Class																					
Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
0	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
1	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
2	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
3	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
4	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
5	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
6	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
7	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
8	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
9	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
10	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
11	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
12	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
13	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
14	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
15	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
16	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
17	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
18	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
19	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
20	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
21	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
22	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
23	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
24	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0

Table 8. Runoff Zone Coefficients – Loss per mile (%)

	Soils Class																					
Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
25	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
26	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
27	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
28	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
29	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
30	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
31	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
32	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
33	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
34	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
35	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
36	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
37	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
38	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
39	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
40	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
41	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
42	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
43	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
44	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
45	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
46	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
47	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
48	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
49	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
50	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0

Table 8. Runoff Zone Coefficients – Loss per mile (%)

	Soils Class																					
Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
51	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
52	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
53	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
54	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
55	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
56	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
57	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
58	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
59	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
60	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
61	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
62	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0
63	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
64	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
65	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
66	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
67	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
68	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
69	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
70	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
71	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
72	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
73	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0
74	3.0	3.0	3.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.0	1.0

Appendix B. Model User’s Setup Guide

Appendix B contains a list, description, and source of all of the input files needed and output files utilized or generated within each program in the RSWB model.

General Input Files:

Active Cells (1 file)

Purpose:

The active cell file contains a list of all cells within the model grid and indicates if the cell is active in the watershed model.

Fields:

Cell	Grid cell index identifier (Integer)
Active Flag	Flag indicating an active cell; 1-Active, 0-Inactive (Integer)

Entries:

A header followed by one entry for each cell in the model

Application Efficiency (1 file)

Purpose:

The application efficiency contains the annual application efficiency values for surface water and groundwater irrigation methods.

Fields:

Year	Year Index value (Integer)
Surface Water Application Efficiency	Base application efficiency for surface water deliveries (Real)
Groundwater Application Efficiency	Base application efficiency for groundwater pumping (Real)

Entries:

A header followed by one entry for each year in the simulation period.

Call Year (1 file)

Purpose:

The call year file allows the user to point to input files from different years. This allows the user to reuse input files rather than create copies with different names.

Fields:

Year	Year Index Value (Integer)
Call Year - Landuse	Year from which landuse data will be pulled (Integer)

Call Year – WBP	Year from which the water balance parameter data will be pulled (integer)
Call Year – Canal	Year from which the canal recharge data will be pulled (integer)
Call Year – M&I	Year from which the municipal and industrial data will be pulled (integer)
Call Year – Miscellaneous	Year from which the Miscellaneous data will be pulled (integer)

Entires:

A header followed by one entry for each year in the simulation period.

Canal Master Input File (1file) {Optional – for inclusion of canal recharge}

Purpose:

This file is used to identify each of the canal recharge data bases to be included in the .RCH file

Fields:

Folder	Folder containing the canal recharge files (String)
File Prefix	Name of the prefix for each annual file (String)

Entries:

A header file followed by one entry for each canal recharge data set to be included in the .RCH file

Canal Recharge Files (Multiple) {Optional – for inclusion of canal recharge}

Purpose:

These files contain the canal recharge volumes and locations.

Number of Files:

One set of files is included for each entry in the Canal Master Input File. Each set of files contains one file for each year during the simulation period.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Value	Total annual canal recharge (Real)
Monthly Value (12)	Twelve monthly canal recharge values (Real)

Entries:

A header followed by one entry for each cell which contains canal recharge from that data set.

Cell Aquifer (1 file)

Purpose:

The Cell Aquifer file defines the portion of pumping within each cell which is assigned to the first layer in the groundwater model.

Fields:

Cell	Grid cell index value (Integer)
Layer 1 Pumping	Portion of the cell pumping assigned to layer 1 in the groundwater model (Between 0-1) (Real)
Assignment Source	Index referencing the source of information used to assign the 'Layer 1 Pumping' value (This value is not used in the modeling process) (Integer)

Entries:

A header followed by one entry for each cell in the model grid

Cell County Relationship (1 file)

Purpose:

The cell county file dictates in which county the cell centroid is located.

Fields:

Cell	Grid cell index value (Integer)
GEOID	County index value used to link the county to the original county shape file (Integer)
County Index	Index value used to link to the county name and state in the County ID file (Integer)

Entries:

A header followed by one entry for each cell in the model grid

County Identification File (1 file)

Purpose:

The county identification file is used to link the county index value to the correct string value of the county name and state name.

Fields:

County Index	Index value used to link the county name and state name to the cell location (Integer)
GEOID	County index value used to link the county to the original county shape file (Integer)
County Name	Name of the county (string)
State Name	Name of the state (string)

Entries:

A header followed by one entry for each of the 565 counties in Nebraska, Wyoming, Colorado, Kansas, Missouri, Iowa, and South Dakota.

Cell Location (1 file)

Purpose:

The cell file contains properties of the cell used to link the appropriate coefficients. It also contains the distance between the cell and the stream gauge at the end of the runoff zone.

Fields:

Cell	Grid cell index value (Integer)
Soil	Soil index value indicating the assigned soil class (Integer)
Coefficient Zone	Index used to link the cell to the appropriate coefficient zone coefficients (Integer)
Runoff Zone	Index used to link the cell to the appropriate drainage basin (Integer)
Miles to Gauge	Distance between the cell centroid and the stream gauge at the end of the runoff zone (Real)

Entries:

A header followed by one entry for each year in the simulation period.

Coefficient File (1 file)

Purpose:

The coefficient file contains the adjustment factors for each coefficient zone. An example file is shown in Table 6.

Fields:

Coefficient Zone	Index defining coefficient zone (Integer)
Soil	Index defining soil (Integer)
Dryland ET Adjustment	Adjustment made to dryland ET (real)
Irrigated ET Adjustment	Adjustment made to irrigated ET (real)
NIR Target	Adjustment made to NIR for targeting irrigation levels (real)
Application Efficiency Adjustment Groundwater	Adjustment made to the application efficiency of groundwater irrigated lands (real)
Surface Loss Fraction Groundwater	Evaporative losses that occur during the application of groundwater irrigation (real)
Dryland ET to Runoff Partition	Partitioning factor used to divide dryland ET between runoff and recharge (real)
Application Efficiency Adjustment Surface Water	Adjustment made to the application efficiency on surface water irrigated lands (real)

Surface Loss Fraction Surface Water	Evaporative loss which occurs during the application of surface water irrigation (real)
Percent to Recharge	Partitioning factor to divide runoff transmission losses between recharge and ET (real)
Deep Percolation Adjustment	Adjustment made to initial Deep Percolation estimates (real)
Runoff Adjustment	Adjustment made to initial Runoff estimates (real)
Comingle Irrigation Split	Factor used to divide the irrigation demand meet by either surface water or groundwater on comingled lands (real)
Recharge Limit Lower Threshold	Point at which the model begins to taper off contributing recharge (real)
Recharge Limit Cap	Upper limit on recharge rates (real)
Runoff Partition Weighting Factor	Weighting instrument used to influence the partitioning factor dividing excess water between runoff and recharge (real)

Entries:

A header followed by one entry for each combination of coefficient zone and soil. (If the coefficients are further divided by another property this will require additional sets of coefficients)

Gridded Water Balance Parameters (Multiple)

Purpose:

The Gridded Water Balance Parameter files contain the initial water balance depth estimate coverages for the entire model domain.

Number of Files:

One set of gridded water balance parameters is used for each simulation. Each set contain coverages for precipitation, evapotranspiration, runoff, deep percolation, and net irrigation requirement.

- There is one precipitation file for each year in the simulation period
- There is one evapotranspiration file for each combination of:
    - Irrigation (dryland or irrigated)
    - Crop
    - Year in the simulation period
- There is one runoff file for each combination of:
    - Irrigation (dryland or irrigated)
    - Crop
    - Year in the simulation period
- There is one deep percolation file for each combination of:

    - Irrigation (dryland or irrigated)
    - Crop
    - Year in the simulation period
- There is one net irrigation requirement file for each combination of:
    - Irrigated crops
    - Year in the simulation period

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Value	Total annual water balance parameter depth (Real)
Monthly Value (12)	Twelve monthly water balance parameter depths (Real)

Entries:

A header followed by one entry for each cell in the grid.

Land Use Files (Multiple)

Purpose:

The land use files define the types of vegetation grown in each cell as well as the source of irrigation (dryland, GW only, SW only, or comingled) for the cell.

Number of files:

There is one file for each year in the simulation period.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Acreage (4 x 12)[12]	This represents four sets of 12 crop coverages. This includes the number of acres of each crop being grown receiving irrigation from each source. The number of acres for each of 12 crops are listed first for dryland crops, followed by groundwater only, surface water only, and then comingled coverages. The sum of all these fields is equivalent to the size of the cell in acres.

Entries:

A header followed by one entry for each active cell in the model domain.

Miscellaneous Pumping Master Input File (1 file) {Optional – for inclusion of Miscellaneous Pumping}

Purpose:

The miscellaneous pumping master file contains a list of all the supplementary miscellaneous pumping data sets which are intended to be included in the .WEL file.

---

[12] The program is set up to read 12 crops even if less are present in the land use data

Fields:

Folder	Name of the folder contain the data set
File Prefix	Name of the file prefix for each annual file in the data set

Entries:

A header followed by one entry for each set of supplementary miscellaneous pumping.

Miscellaneous Pumping (Multiple) {Optional – for inclusion of Miscellaneous Pumping}

Purpose:

These files contain volume and location of the miscellaneous pumping.

Number of files:

One set of files is included for each entry in the Miscellaneous Pumping Master Input File. Each set of files contains one file for each year during the simulation period.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Value	Total annual miscellaneous pumping (Real)
Monthly Values (12)	Twelve monthly miscellaneous values (Real)

Entries:

A header followed by one entry for each cell which contains miscellaneous pumping from that data set.

Miscellaneous Recharge Master Input File (1 file) {Optional – for inclusion of Miscellaneous Recharge}

Purpose:

The miscellaneous recharge master file contains a list of all the supplementary miscellaneous recharge data sets which are intended to be included in the .WEL file.

Fields:

Folder	Name of the folder contain the data set
File Prefix	Name of the file prefix for each annual file in the data set

Entries:

A header followed by one entry for each set of supplementary miscellaneous recharge.

Miscellaneous Recharge (Multiple) {Optional – for inclusion of Miscellaneous Recharge}

Purpose:

These files contain volume and location of the recharge pumping.

Number of files:

One set of files is included for each entry in the Miscellaneous Recharge Master Input File. Each set of files contains one file for each year during the simulation period.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Value	Total annual miscellaneous recharge (Real)
Monthly Values (12)	Twelve monthly recharge values (Real)

Entries:

A header followed by one entry for each cell which contains miscellaneous recharge from that data set.

Municipal and Industrial Pumping Master Input File (1 file) {Optional – for inclusion of M&I Pumping}

Purpose:

The municipal and industrial pumping master file contains a list of all the supplementary municipal and industrial pumping data sets which are intended to be included in the .WEL file.

Fields:

Folder	Name of the folder contain the data set
File Prefix	Name of the file prefix for each annual file in the data set

Entries:

There is one entry for each set of supplementary municipal and industrial pumping. Note this file does not include a header.

Municipal and Industrial Pumping (Multiple) {Optional – for inclusion of M&I Pumping}

Purpose:

These files contain volume and location of the municipal and industrial pumping.

Number of files:

One set of files is included for each entry in the Municipal and Industrial Master Input File. Each set of files contains one file for each year during the simulation period.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Value	Total annual M&I pumping (Real)
Monthly Values (12)	Twelve monthly M&I values (Real)

Entries:

A header followed by one entry for each cell which contains municipal and industrial pumping from that data set.

River Cells (1 file)

Purpose:

The River Cells file is used to define which cells are river cells in the groundwater model necessitating the movement of pumping to surrounding cell. The file further defines how many and which cell the pumping will be moved into.

Fields:

Cell	Grid cell index value (Integer)
River Cell Flag	Flag indicating that pumping needs to be relocated (Integer)
Count	Number of new cells the pumping will be divided among (Integer)
<Count> New Cells	List of new cells to which the pumping will be divided (Integer) there needs to be <count> number of fields for the new cells

Entries:

A header followed by one entry for each cell in the model grid.

Runoff Zone Coefficients (1 file)

Purpose:

The runoff zone coefficient file contains the coefficient values for the parameters controlled by the coefficient zone.

Fields:

Runoff Zone	Runoff zone index (Integer)
Loss Per Mile (# of soils)	rate (% per mile) at which runoff is lost to ET or recharge between the field and stream gauge (Real)

Entries:

A header followed by one entry per runoff zone.

Soil Index (1 file)

Purpose:

This file relates the soil index to the CROPSIM soil class.

Fields:

Soil Index	Soil index (Integer)
CROPSIM Soil	CROPSIM soil class (Integer)

Entries:

A header followed by one entry for each soil class in the model.

Program: Irrigation Application and Demand

File Name: IrrDemand_10.0.F90

Purpose:

The IAD program uses the distributed NIR and land use files to estimate the irrigation demand for surface water, groundwater, and comingled lands. The program then creates output files for use in the WSPP program.

Input Files:

Application Efficiency – General Input
Call Year – General Input
Cell Location – General Input
Coefficient File – General Input
Gridded Water Balance Parameters; NIR – General Input
Land Use– General Input

Program Inputs:

Endyr	2013	Simulation end year
LandUse	'LPMTLU'	Prefix for the land use files
Ncells	98700	Number of cells in complete model grid
Nsoils	22	Number of soil classes
Nzones	14	Number of coefficient zones
RunName	'008e'	Suffix to the coefficient file
Startyr	1960	Simulation start year

Directory Locations:

INDIR	Location of the input files
LUDIR	Location of the land use files
OUTDIR	Location to write the results
WBPDIR	Location of the gridded water balance parameters

Output Files:

Surface Water Deliveries (Annual Files)

Purpose:

This file contains the surface water deliveries on surface water only lands for each cell in the relevant year. The file contains the total volume delivered each month as well as the depth of irrigation water that was delivered to each crop each month.

File Name:

SWDXXXX.txt

Location:

OUTDIR//SWD\

Number of Files:

There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Deliveries	Volume of deliveries (Real; AF)
Monthly Deliveries (12)	Volume of deliveries (Real; AF)
{	
Annual Crop Delivery Depth	Annual depth delivered to crop (Real; ft)
Monthly Crop Delivery Depth (12)	12 Monthly depth delivered to crop (Real; ft)
} Repeated for 12 crops possible	

Entries:

A header followed by one entry for each cell with surface water only lands which was delivered surface water.

Groundwater Pumping(Annual Files)

Purpose:

This file contains the pumping on groundwater only lands for each cell in the relevant year. The file contains the total volume pumped each month as well as the depth of irrigation water that was pumped on each crop each month.

File Name:

GWPXXXX.txt

Location:

OUTDIR//GWP\

Number of Files:

There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Pumping	Volume of pumping (Real; AF)
Monthly Pumping (12)	Volume of pumping (Real; AF)
{	
Annual Crop Pumping Depth	Annual depth pumped to crop (Real; ft)

Monthly Crop Pumping Depth (12)	12 Monthly depth pumped to crop (Real; ft)
} Repeated for 12 crops possible	

Entries:

A header followed by one entry for each cell with groundwater only lands which was pumped groundwater.

Comingled Deliveries (Annual Files)

Purpose:

This file contains the surface water deliveries on comingled lands for each cell in the relevant year. The file contains the total volume delivered each month as well as the depth of irrigation water that was delivered to each crop each month.

File Name:

CODXXXX.txt

Location:

OUTDIR//COD\

Number of Files:

There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Deliveries	Volume of deliveries (Real; AF)
Monthly Deliveries (12)	Volume of deliveries (Real; AF)
{	
Annual Crop Delivery Depth	Annual depth delivered to crop (Real; ft)
Monthly Crop Delivery Depth (12)	12 Monthly depth delivered to crop (Real; ft)
} Repeated for 12 crops possible	

Entries:

A header followed by one entry for each cell with comingled lands which was delivered surface water or received groundwater pumping.

Comingled Pumping (Annual Files)

Purpose:

This file contains the pumping on comingled lands for each cell in the relevant year. The file contains the total volume pumped each month as well as the depth of irrigation water that was pumped on each crop each month.

File Name:
COPXXXX.txt

Location:
OUTDIR//COP\

Number of Files:
There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Annual Pumping	Volume of pumping (Real; AF)
Monthly Pumping (12)	Volume of pumping (Real; AF)
{	
Annual Crop Pumping Depth	Annual depth pumped to crop (Real; ft)
Monthly Crop Pumping Depth (12)	12 Monthly depth pumped to crop (Real; ft)
} Repeated for 12 crops possible	

Entries:
A header followed by one entry for each cell with comingled lands on which was pumped groundwater or delivered surface water.

Program: Water Supply Partitioning Program

File Name: WSPP_10.0.F90

Purpose:

The purpose of WSPP is to partition precipitation and applied irrigation between evapotranspiration, recharge, runoff and change in soil water content. Additionally WSPP is used to adjust the parameters of the water balance from the idealized conditions in CROPSIM, through calibration, to more accurately reflect the conditions experienced in the field. This is accomplished using the distributed water balance parameters, land use classification, and applied irrigation volumes. WSPP is capable of incorporating either the estimated irrigation amounts developed in the IAD or an irrigation data set developed outside the model (e.g. metered well pumping records).

Input Files:

Application Efficiency – General Input
Call Year – General Input
Cell Location – General Input
Coefficient File – General Input
Comingled Deliveries – IAD
Comingled Pumping – IAD
Gridded Water Balance Parameters; NIR, ET, RO, & DP – General Input
Groundwater Pumping – IAD
Land Use– General Input
Surface Water Deliveries – IAD

Program Inputs:

DPonly	0	Flag indicating dryland only
Endyr	2013	Simulation end year
Landuse	‘LPMTLU’	Prefix for the land use files
MaxRO	0.95	Maximum runoff split
MinRO	0.05	Minimum runoff split
Ncells	98700	Number of cells in the model grid
Nsoils	22	Number of soil classes
Nzone	14	number of coefficient zones
RunName	‘008e’	Suffix to the coefficient file
Startyr	1960	Simulation start year
SWonly	0	Flag indicating only surface water deliveries

Directory Locations:

INDIR	Location of the input files
LUDIR	Location of the land use files
OUTDIR	Location to write the results

WBPDIR	Location of the gridded water balance parameters

Output Files:

WSPP Out (Annual Files)

Purpose:

This file contains the monthly cell totals of runoff and direct recharge.

File Name:

WSPPOutXXXX.txt

Location:

OUTDIR//WSPP_Out\

Number of Files:

There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant Year (Integer)
Annual DP	Annual deep percolation total for the cell (Real; AF)
Monthly DP (12)	Monthly deep percolation totals for the cell (Real; AF)
Annual RO	Annual field runoff total for the cell (Real; AF)
Monthly RO (12)	Monthly field runoff totals for the cell (Real; AF)

Entries:

A header followed by one entry for each active model cell

Pump File (Annual Files)

Purpose:

This file contains the monthly cell totals of agricultural pumping.

File Name:

PumpXXXX.txt

Location:

OUTDIR//Pump\

Number of Files:

There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)

Year	Relevant Year (Integer)
Annual Pumping	Annual deep percolation total for the cell (Real; AF)
Monthly Pumping (12)	Monthly deep percolation totals for the cell (Real; AF)

Entries:
A header followed by one entry for each active model cell

RAW File (Annual Files)

Purpose:
This file contains the water balance totals for each transaction made in the WSPP program.

File Name:
RAW_WSPP.txt

Location:
OUTDIR//RAW\

Number of Files:
There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant Year (Integer)
Month	Relevant Month (Integer) 0 for annual total
Crop	Crop index value (Integer)
Soil	Soil class index (Integer)
Irrigation Type	Source of irrigation (Integer)
Coefficient Zone	Relevant coefficient zone (Integer)
Runoff Zone	Relevant runoff zone (Integer)
Acres	Segment acres (Real, acres)
Pumping	Applied pumping (Real, AF)
SW Deliveries	Surface water deliveries (Real, AF)
Evapotranspiration	Direct evapotranspiration (Real, AF)
Runoff	Direct runoff (Real, AF)
Deep Percolation	Direct deep percolation (Real, AF)
Surface Loss	Evaporative losses from the act of applying irrigation (Real, AF)
Post Surface Loss Irrigation	Applied irrigation minus surface losses (Real, AF)
Delta Irrigation	Irrigation deficit (Real, AF)
ET gain	Additional evapotranspiration from the application of irrigation water (Real, AF)
Delta ET	Difference between full ET and the resultant ET from the defined level of irrigation (Real, AF)

ET base	Expected ET if no irrigation water is applied (Real, AF)
DP1	Adjusted deep percolation from the Soil Water Balance Model (Real, AF)
DP2	Split of excess water assigned to recharge (Real, AF)
RO1	Adjusted runoff from the Soil Water Balance Model (Real, AF)
RO2	Split of excess water assigned to runoff (Real, AF)
Excess Water	Applied water not specifically assigned to ET or change in soil water content (Real, AF)
ET Transfer	Runoff or deep percolation adjustment from the soil water balance model (Real, AF)
CS NIR minus ET	The net irrigation requirement minus the ET from the soil water balance model (Real, AF)
DP2RO	Conversion of recharge to runoff from high recharge events (Real, AF)

Entries:
A header followed by one entry for each transaction preformed in the WSPP program.

Program: Make Well
File Name: Make_WEL_10.0.f90

Purpose:

The Make Well program compiles all sources of groundwater pumping, moves pumping from river cells to nearby active non-river cells, and assigns the pumping to the appropriate aquifer layer. With this information the program creates an annual section formatted appropriately for the .WEL file.

Input Files:

Cell Aquifer – General Input
Miscellaneous Pumping Master Input File – General Input
Miscellaneous Pumping – General Input
Municipal and Industrial Master Input File – General Input
Municipal and Industrial Pumping – General Input
Pump File – WSPP
River Cells – General Input

Program Inputs:

Cellmoves	4	Number of possible cells to move river cell pumping to
Csize	160.0	Size of the model cell in acres
Endyr	2013	Simulation end year
Layer	1	Inconsequential
MISP	0	Flag indicating the existence of miscellaneous pumping
Muni	1	Flag indicating the existence of municipal and industrial pumping

Ncells	98700	Number of cells in complete model grid
Ncols	282	Number of columns in the model grid
Startyr	1960	Simulation start year
SwcYr	1986	Switch year; the point at which stress period length changes from annual to monthly

Directory Locations:

INDIR	Location of the input files
MIDIR	Location of the municipal and industrial pumping data folders
MISCDIR	Location of the miscellaneous pumping data folders
OUTDIR	Location of the agricultural pumping data
OUTDIR2	Location to write the results

*OUTDIR and OUTDIR2 should have the same location, but will differ if you are trying to calibrate parameters affecting the assignment of pumping to layers or cells and want to skip the previous steps in the modeling process by using the results from a previous run. The author of this guide would caution the user to take care when doing this to ensure that the results are used responsibly.

Output Files:

Pump Values (1 file)

Purpose:

This file records the annual pumping total for each cell for each year of the model simulation. This file can then be used in ArcGIS with the tool make query table to develop a time series animation of pumping totals.

File Name:

Pmp_values.txt

Location:

OUTDIR2

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
%2Layer 1	Portion of pumping that is assigned to layer 1 (Real)
Pumping	Annual cell pumping total (Real; in)

Entries:

A header followed by one entry for each cell for each year in the simulation period.

.WEL File (Annual Files)

Purpose:

This is an annual version of the properly formatted .WEL file. These files do not include the headers located at the beginning of the file but do include the appropriate stress period header. The file also includes a value for the maximum enter in any stress period during the year.

File Name:
LPMTXXXX.WEL

Location:
OUTDIR2//WEL\

Number of Files:
There is one file created for each year of the simulation.

Fields:
There are three formats:
Format 1)

MLPSP	Maximum Lines per stress period

Format 2)

LPSP	Lines per stress period, there is one entry for each aquifer layer pumping is extracted from for each cell with pumping in it. Extracting from one layer LPSP + 1; extracting from two layers LPSP + 2.

Format 3)

Layer	Aquifer layer the pumping is being extracted from (Integer)
Row	Row index of the cell (Integer)
Column	Column index of the cell (Integer)
Pumping	Negative rate of pumping (Real, cfd)

Entries:
There is one entry of format 1 at the top of the file
There is one entry of format 2 at the beginning of each stress period. The number of stress periods is 1 if the current year is before the switch year and 12 if the current year is after the switch year.
There are <LPSP> entries in each stress period.

Well Check (Annual Files)

Purpose:
This file keeps a record each entry into the .WEL file in vector format for quality control efforts.

File Name:
Well_chkXXXX.txt

Location:

OUTDIR2//Well_chk\

Number of Files:
There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Layer	Aquifer layer where the pumping is being extracted (Integer)
Well Data Source	Data set used to define the aquifer layer to extract the pumping (Integer)
Row	Row index (Integer)
Column	Column index (Integer)
Year	Relevant year (Integer)
Month	Relevant month (Integer)
Days in Stress Period	Number of days in the stress period (Integer)
Pumping	Pumping being extracted (Real; AF per day)
Pumping	Pumping being extracted (Real; cubic feet per day)

Entries:
A header followed by one entry for each combination of cell and layer from which pumping was extracted.

Program: Compile Well
File Name: Compile_Wel.f90

Purpose:

Combine the annual .WEL files into a single .WEL file for inclusion into the groundwater model.
Combine the annual Well Check files into a single Well Check file.

Input Files:

.WEL File (annual) – Make Well
Well Check (annual) – Make Well

Program Inputs:

Endyr	2013	Simulation end year
Startyr	1960	Simulation start year

Directory Locations:

OUTDIR	Location to write the results

Output Files:

.WEL File (1 file)

Purpose:

This is the properly formatted .WEL file containing each stress period during the simulation period. The file consists of the appropriate file headers, stress period headers, and pumping rates which include layer, and cell location.

File Name:

LPMT.WEL

Location:

OUTDIR\

Fields:

There are four formats:

Format 1)

ModFlow headers; see the Modflow documentation for a description and definition of the .WEL file headers

Format 2)

MLPSP	Maximum Lines per stress period

Format 3)

LPSP	Lines per stress period, there is one entry for each aquifer layer pumping is extracted from for each cell with pumping in it. Extracting from one layer LPSP + 1; extracting from two layers LPSP + 2.

Format 4)

Layer	Aquifer layer the pumping is being extracted from (Integer)
Row	Row index of the cell (Integer)
Column	Column index of the cell (Integer)
Pumping	Negative rate of pumping (Real, cfd)

Entries:

The top few lines consist of .WEL File headers

There is one entry of format 2 indicating the maximum lines in any stress period.

There is one entry of format 3 at the beginning of each stress period. The number of stress periods is 1 if the current year is before the switch year and 12 if the current year is after the switch year. The value indicates the number of line in the stress period (LPSP)

There are <LPSP> entries in each stress period.

Well Check (1 file)

Purpose:

This file keeps a record each entry into the .WEL file in vector format for quality control efforts.

File Name:

Well_chk.txt

Location:
OUTDIR\

Fields:

Cell	Grid cell index value (Integer)
Layer	Aquifer layer where the pumping is being extracted (Integer)
Well Data Source	Data set used to define the aquifer layer to extract the pumping (Integer)
Row	Row index (Integer)
Column	Column index (Integer)
Year	Relevant year (Integer)
Month	Relevant month (Integer)
Days in Stress Period	Number of days in the stress period (Integer)
Pumping	Pumping being extracted (Real; AF per day)
Pumping	Pumping being extracted (Real; cubic feet per day)

Entries:
A header followed by one entry for each combination of cell and layer from which pumping was extracted.

Program: Make Recharge
File Name: Make_RCH_10.0.f90

Purpose:

The Make Recharge program partitions edge of field runoff and compiles all sources of recharge into annual properly formatted .RCH files. The file also creates quality control files for the sources of field recharge, canal recharge, stream flow contributions, and runoff partitioning.

Input Files:

Canal Master Input File – General Input
Canal Recharge Files – General Input
Cell Location – General Input
Coefficient File – General Input
Miscellaneous Recharge Master Input File – General Input
Miscellaneous Recharge – General Input
Runoff Zone Coefficient – General Input
WSPP Out – WSPP

Program Inputs:

CnlRch	0	Flag indicating the inclusion of canal recharge

Csize	160.0	Size of the model cell in acres
Endyr	2013	Simulation end year
MiscRch	0	Flag indicating the inclusion of miscellaneous recharge
Ncell	98700	Number of cells in the model grid
Ncols	282	Number of columns in the model grid
Nrows	350	Number of rows in the model grid
Nsoils	22	Number of soil classes
Nzone	14	Number of coefficient zones
RunName	'008e'	Suffix for the coefficient file
Rzone	74	Number of runoff zones
Startyr	1960	Simulation start year
SwcYr	1986	Switch year; the point at which stress period length changes from annual to monthly

Directory Locations:

CNLDIR	Location of the canal recharge files
INDIR	Location of the input files
OUTDIR	Location of the WSPP results included in the .RCH file
OUTDIR2	Location to write the results

*OUTDIR and OUTDIR2 should have the same location, but will differ if you are trying to calibrate parameters and want to skip the previous steps in the modeling process by using the results from a previous run. The author of this guide would caution the user to take care when doing this to ensure that the results are used responsibly.

Output Files:

Recharge Values (1 file)

Purpose:

This file records the annual recharge total for each cell for each year of the model simulation. This file can then be used in ArcGIS with the tool make query table to develop a time series animation of recharge totals.

File Name:

Rch_values.txt

Location:

OUTDIR2

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Recharge	Annual cell pumping total (Real; in)

Entries:

A header followed by one entry for each cell for each year in the simulation period.

.RCH File (Annual Files)

Purpose:

This file compiles all the sources of recharge into a set of properly formatted .RCH files. The file contains all of the stress periods which occur within a single year with the appropriate headers for each stress period.

File Name:

MOTrXXXX.RCH

Location:

OUTDIR2//RCH\

Number of Files:

There is one file created for each year of the simulation.

Fields:

There are two sets of formats:

Format 1)

Stress Period Headers, a set of MODFLOW directed headers; see MODFLOW documentation for definitions and descriptions

Format 2)

Recharge rates (Real; Feet per day) The recharge rates are organized in a matrix in which each cell is represented in each stress period. Within each stress period the cells are broken into groups defined by a row. Each row contains <ncols> entries. These entries are organized into ten cell lines followed by a partial line. For the LPMT model with 282 lines there are 28 ten cell lines and on 2 cell line.

Entries:

The file consists of the number of stress periods in the year (1 or 12). Each stress period has the stress period headers followed by the recharge rates for each cell organized as described above in format 2.

Irrigation and Precipitation Recharge(Annual Files)

Purpose:

This file keeps track of the recharge as a result of irrigation and precipitation for quality control purposes.

File Name:

IrrPrecXXXX.txt

Location:
OUTDIR2//IrrPrec\

Number of Files:
There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Runoff Zone	Relevant runoff zone (Integer)
Row	Row index (Integer)
Column	Column index (Integer)
Year	Relevant year (Integer)
Month	Relevant month (Integer)
Days in month	Number of days in the month (Integer)
Direct Recharge	Field recharge (Real, AF)
Indirect Recharge	Recharge from transmission losses (Real, AF)
Canal Seepage	Recharge from canal transmission losses (Real, AF)
Miscellaneous Recharge	Recharge for non RSWB source (Real, AF)
Loss Per Mile	Rate at which runoff becomes transmission loss (Real, %/mi)
Miles to Gauge	Distance between cell and stream gauge (Real, mi)
Percent to Recharge	Partitioning factor for transmission losses (Real)
Total Recharge	Sum of all recharge (Real, AF)
Agricultural Recharge	Sum of direct and indirect recharge (Real, AF)

Entries:
A header followed by one entry for each cell month combination in which the cell experiences recharge.

Canal Recharge Summary(Annual Files)

Purpose:
This file keeps track of the canal recharge used in the model.

File Name:
CanalXXXX.txt

Location:
OUTDIR2//Canal\

Number of Files:
There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Row	Row index (Integer)
Column	Column index (Integer)
Year	Relevant year (Integer)
Month	Relevant month (Integer)
Days in Month	Number of days in Month (Integer)
Canal Recharge	Canal seepage (Real; AF)
Canal Recharge	Canal seepage (Real; ft/d)

Entries:

A header followed by one entry for each cell month combination in which a cell experiences canal recharge.

Runoff Contributions to Stream Flow (Annual Files)

Purpose:

This file keeps track of the portion of runoff which makes it to the stream gauge.

File Name:

SFXXXX.txt

Location:

OUTDIR2//SF\

Number of Files:

There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Runoff Zone	Relevant Runoff Zone (Integer)
Row	Row index (Integer)
Column	Column index (Integer)
Year	Relevant year (Integer)
Month	Relevant month (Integer)
Days in Month	Number of days in Month (Integer)
Runoff Contributions to stream flow	Portion of runoff which makes it to the stream gauge (Real; AF)
Runoff	Field runoff (Real; AF)
Loss per Mile	Rate at which runoff is lost during transit (Real; %/mi)
Miles to Gauge	Distance between the cell and the stream gauge (Real; mi)

Runoff Contributions to stream flow	Portion of runoff which makes it to the stream gauge (Real; AF)

Entries:

A header followed by one entry for each cell month combination in which a cell experiences recharge.

Runoff Balance (Annual Files)

Purpose:

This file keeps track of the partitioned runoff balance.

File Name:

ROBalXXXX.txt

Location:

OUTDIR2//ROBal\

Number of Files:

There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Month	Relevant month (Integer)
Field Runoff	Direct runoff (Real; AF)
Losses to Recharge	Transmission losses to recharge (Real; AF)
Losses to ET	Transmission losses to ET (Real; AF)
Runoff Contributions to stream flow	Portion of runoff which makes it to the stream gauge (Real; AF)

Entries:

A header followed by one entry for each cell month combination in which a cell experiences runoff.

Annual Recharge (Annual Files)

Purpose:

This file provides a summary of all recharge sources by cell.

File Name:

AnnRchXXXX.txt

Location:

OUTDIR2//AnnRch\

Number of Files:
There is one file created for each year of the simulation.

Fields:

Cell	Grid cell index value (Integer)
Year	Relevant year (Integer)
Month	Relevant month (Integer)
Total Recharge	Total recharge (Real; AF)
Direct Recharge	Field recharge (Real; AF)
Indirect Recharge	Transmission losses to recharge (Real; AF)
Canal Recharge	Canal Seepage (Real; AF)
Miscellaneous Recharge	Other recharge values developed outside the RSWB but included in the .RCH file (Real; AF)
Runoff Contributions to stream flow	Portion of runoff which makes it to the stream gauge (Real; AF)
Losses to ET	Transmission losses to ET (Real; AF)
Direct Runoff	Field Runoff (Real; AF)

Entries:
A header followed by one entry for each cell month combination in which a cell experiences recharge.

Program: Compile Recharge

File Name: Compile_RCH.f90

Purpose:

Combine the annual .RCH files into a single .RCH file with the appropriate headers for inclusion into the groundwater model.

Input Files:

.RCH File (annual) – Make Recharge

Program Inputs:

Endyr	2013	Simulation end year
Filename	'MOTr'	Name of the annual .RCH file
Fileout	'LPMT.RCH'	Name of the combined .RCH file
Foldname	'RCH'	Location of the annual .RCH files
Startyr	1960	Simulation start year

Directory Locations:

OUTDIR	Location to write the results

Output Files:

.RCH File (1 file)

Purpose:

This is the properly formatted .RCH file containing each stress period during the simulation period. The file consists of the appropriate file headers, stress period headers, and recharge rates.

File Name:

<Fileout>

Location:

OUTDIR\

Fields:

There are three sets of formats:

Format 1)

File headers, a set of MODFLOW directed headers; see MODFLOW documentation for definition and descriptions

Format 2)

Stress Period Headers, a set of MODFLOW directed headers; see MODFLOW documentation for definitions and descriptions

Format 3)

Recharge rates (Real; Feet per day) The recharge rates are organized in a matrix in which each cell is represented in each stress period. Within each stress period the cells are broken into groups defined by a row. Each row contains <ncols> entries. These entries are organized into ten cell lines followed by a partial line. For the LPMT model with 282 lines there are 28 ten cell lines and on 2 cell line.

Entries:

The file consists of the file headers followed by a set of entries for each stress period. Each stress period has the stress period headers followed by the recharge rates for each cell organized as described above in format 3.

Program: WSPP Report

File Name: WSPP_Report10.0.f90

Purpose:

The WSPP Report program creates a set of annual and monthly summaries of the water balance based upon defined geographical areas, soils, crops, and irrigation sources.

Input Files:

Call Year – General Input
Cell County Relationship – General Input
Cell Location – General Input
Coefficient File – General Input
County Identification File – General Input
RAW file – WSPP
Runoff Zone Coefficient File – General Input
Gridded Water Balance Parameter; Precipitation – General Input

Program Inputs:

CntyCell	'Cell_County.txt'	Name of the cell county relationship file
CntyID	'CountID.txt'	Name of county identification file
Endyr	2013	Simulation end year
Ncells	98700	Number of cells in the model grid
Ncounty	565	Number of counties in Nebraska and bordering states
Ncrops	12	Number of possible crops
Nczones	14	Number of coefficient zones
Nrzones	74	Number of runoff zones
Nsoils	22	Number of soils
RunName	'008e'	Prefix for the coefficient file
Startyr	1960	Simulation start year

Directory Locations:

INDIR	Location of the input files
OUTDIR	Location to write the results
RAWDIR	Location of the results folder with the RAW file
WBPDIR	Location of the water balance parameter coverages

Output Files:

Annual Summary Files (Multiple)

Purpose:

Contains a water balance summary based upon defined characteristics.

File Name:

ZZZ_YYY_annXXXX.txt

ZZZ_YYY_monXXXX.txt

ZZZ represents the geographic areas over which the summary is being made. Areas include Regional (Reg), county (Cnty), runoff zone (ROZ), and coefficient zone (CoefZ).
YYY represents the types of discretization made within the geographic area; including total (Tot), Crop (Crop), Irrigation Source (IrrS), Soil (Soil), Crop & Irrigation Source (CropIrrs), Crop & Soil (CropSoil), Soil & Irrigation Source (SoilIrrs), Crop, Soil, & Irrigation source (CSI)

Location:
OUTDIR2//Report\<WWWW>\Annual
WWWW is CoefZone, County, Regional, or Runoff Zone

Number of Files:
There is one file created for each year of the simulation for each of the combination described under file names. Note all of the summaries for one combination are included in one file. Example all county total annual files are included in a single file.

Fields:

Year	Relevant Year (Integer)
Month	Relevant Month (Integer)
<Summary Specific Variables>	
Acres	Acres included in the summary (Real; Acres)
Precip	Precipitation (Real; AF)
Pumping	Groundwater pumping (Real; AF)
Deliveries	Surface water deliveries (Real; AF)
ET	Direct evapotranspiration (Real; AF)
RO	Direct runoff (Real; AF)
DP	Direct deep percolation (Real; AF)
SL	Evaporative losses from the act of applying irrigation (Real; AF)
PSL	Irrigation after evaporative losses are removed (Real; AF)
DAP	Change in applied irrigation (Real; AF)
ETg	Increase in evapotranspiration from the application of irrigation (Real; AF)
DET	Evapotranspiration adjustment (Real; AF)
ETb	Expected evapotranspiration if no irrigation was applied (Real; AF)
DP1	Adjusted deep percolation from soil water balance model (Real; AF)
DP2	Deep percolation from split of excess water (Real; AF)
RO1	Adjusted runoff from soil water balance model (Real; AF)
RO2	Runoff from split of excess water (Real; AF)
ETtrans	Runoff and deep percolation adjustment (Real; AF)
DP2RO	Deep percolation converted to runoff during high recharge events (Real; AF)

SF	Runoff contributions to stream flow (Real; AF)
RO2DP	Runoff losses to recharge (Real; AF)
RO2ET	Runoff losses to evapotranspiration (Real; AF)

The summary specific variables include combinations of:
Crop Index
Irrigation source Index
Soil Index
County Index
County Name
State Name
Coefficient Zone
Runoff Zone

Entries:

There is one entry for each combination of geographic area, time periods (within one year), discretization within the geographic area represented within the model area.

Program: Compile WSPP Report
File Name: Compile_WSPP_Report.f90

Purpose:

The WSPP Report program creates a set of annual and monthly summaries of the water balance based upon defined geographical areas, soils, crops, and irrigation sources.

Input Files:

Annual Summary Files – WSPP Report

Program Inputs:

Endyr	2013	Simulation end year
RepTypes	4	Number of types of geographical areas
RepGroup	8	Number of types of discretization combinations
RepPeriods	2	Number of types of temporal summaries
Startyr	1960	Simulation start year

Directory Locations:

OUTDIR	Location to write the results

Output Files:

Summary Files (Multiple)

Purpose:

Contains a water balance summary based upon defined characteristics over a define period.

File Name:
ZZZ_YYY_ann.txt
ZZZ_YYY_mon.txt

ZZZ represents the geographic areas over which the summary is being made. Areas include Regional (Reg), county (Cnty), runoff zone (ROZ), and coefficient zone (CoefZ).
YYY represents the types of discretization made within the geographic area; including total (Tot), Crop (Crop), Irrigation Source (IrrS), Soil (Soil), Crop & Irrigation Source (CropIrrs), Crop & Soil (CropSoil), Soil & Irrigation Source (SoilIrrs), Crop, Soil, & Irrigation source (CSI)

Location:
OUTDIR2//Report\<WWWW>\Annual
WWWW is CoefZone, County, Regional, or Runoff Zone

Number of Files:
There is one file created for each year of the simulation for each of the combination described under file names. Note all of the summaries for one combination are included in one file. Example all county total annual files are included in a single file.

Fields:

Year	Relevant Year (Integer)
Month	Relevant Month (Integer)
<Summary Specific Variables>	
Acres	Acres included in the summary (Real; Acres)
Precip	Precipitation (Real; AF)
Pumping	Groundwater pumping (Real; AF)
Deliveries	Surface water deliveries (Real; AF)
ET	Direct evapotranspiration (Real; AF)
RO	Direct runoff (Real; AF)
DP	Direct deep percolation (Real; AF)
SL	Evaporative losses from the act of applying irrigation (Real; AF)
PSL	Irrigation after evaporative losses are removed (Real; AF)
DAP	Change in applied irrigation (Real; AF)
ETg	Increase in evapotranspiration from the application of irrigation (Real; AF)
DET	Evapotranspiration adjustment (Real; AF)
ETb	Expected evapotranspiration if no irrigation was applied (Real; AF)
DP1	Adjusted deep percolation from soil water balance model (Real; AF)
DP2	Deep percolation from split of excess water (Real; AF)
RO1	Adjusted runoff from soil water balance model (Real; AF)
RO2	Runoff from split of excess water (Real; AF)

ETtrans	Runoff and deep percolation adjustment (Real; AF)
DP2RO	Deep percolation converted to runoff during high recharge events (Real; AF)
SF	Runoff contributions to stream flow (Real; AF)
RO2DP	Runoff losses to recharge (Real; AF)
RO2ET	Runoff losses to evapotranspiration (Real; AF)

The summary specific variables include combinations of:
Crop Index
Irrigation source Index
Soil Index
County Index
County Name
State Name
Coefficient Zone
Runoff Zone

Entries:

There is one entry for each combination of geographic area, time period, discretization within the geographic area represented within the model area.

Appendix C. Sample Calculations

The following example will go through the calculations for cell 23,546 in the year 1985. The location of the cell is 84-140. Some tolerance should be given for the effects of rounding when following the sample calculations. A higher number of decimals were kept through the development of this process than were reported in the tables.

Land use:

Groundwater only crops	160.0	acres
Corn	129.66	acres
Alfalfa	2.76	acres
Soybean	27.58	acres

However, for simplicity, all calculations will be made under the assumption that the entire cell is composed of groundwater only corn (160.0 acres).

From the Cell Location File:

Soil Index	19	
Coefficient Zone	2	
Runoff Zone	22	
Distance to Gauge	10.04	miles

From the Soil Index File:

Soil Class	831

From the Coefficient File:

Dryland ET Adjustment	$ADJ_{ET, dry}$	0.937
Irrigated ET Adjustment	$ADJ_{ET, irr}$	0.937
NIR Target	$Target_{NIR}$	0.850
Application Efficiency Adjustment – Groundwater	$ADJ_{AE, GW}$	1.000
Surface Loss Fraction – Groundwater	FSL_{GW}	0.020
Dryland ET to Runoff	DryET2RO	0.400
Application Efficiency Adjustment – Surface Water	$ADJ_{AE, SW}$	1.000
Surface Loss Fraction Surface Water	FSL_{SW}	0.050
Percent to Recharge	%2Rch	0.065
Deep Percolation Adjustment	ADJ_{DP}	1.000
Runoff Adjustment	ADJ_{RO}	1.000

Comingled Split	CM_{split}	1.000	
Deep Percolation Lower Threshold	DP_{ll}	4.000	in
Deep Percolation Cap	DP_{cap}	8.000	in
Runoff Weighting Factor	RO_fDP	1.000	

From the Runoff Zone Coefficient File:

Loss per Mile	lpm	0.015

From the Application Efficiency File

Application Efficiency – Groundwater	AE_{GW}	0.800
Application Efficiency – Surface Water	AE_{SW}	0.650

The first step is to determine the three closest weather stations to the centroid of the cell. Using the NAD_1983_StatePlane_Nebraska_FIPS_2600_Feet projection in ArcGIS the following information was found:

Cell Location – x	2,508,000	feet
Cell Location – y	893,640	feet

Using Equation 4, the three nearest weather stations were found

$$dist = \sqrt{(cell_x - stat_x)^2 + \left(cell_y - stat_y\right)^2} \tag{32}$$

dist	distance between the cell centroid and the weather station (ft)
$cell_x$	x-location of the cell (ft)
$cell_y$	y-location of the cell (ft)
$stat_x$	x-location of the weather station (ft)
$stat_y$	y-location of the weather station (ft)

The three nearest stations are:

Station 1:

Name:	Wayne, NE	
NWS Code:	c259045	
Alias:	WAYN	
Location – x:	2,449,725	feet
Location – y:	890,662	feet
Distance from cell:	58,351	feet

Station 2:

Name:	Walthill, NE	
NWS Code:	c258935	
Alias:	WALT	
Location – x:	2,594,442	feet
Location – y:	863,301	feet
Distance from cell:	91,611	feet

Station 3:

Name:	West Point, NE	
NWS Code:	c259200	
Alias:	WEST	
Location – x:	2,536,294	feet
Location – y:	751,634	feet
Distance from cell:	144,797	feet

An inverse weighted distance is used to calculate the Gridded Water Balance Parameters. The weighting factor is calculated by Equations 33-35.

$$x_i = \frac{1}{dist_i^p} \tag{33}$$

x_i	the ith station weight
$dist_i$	the distance between the cell centroid and weather station (ft)
p	weighting factor (p = 2)

$$x_{sum} = \sum_{i=1}^{n} x_i \tag{34}$$

x_i	the ith station weight
x_{sum}	the total weight of all stations
n	the total number of contributing stations

$$weight_i = \frac{x_i}{x_{sum}} \tag{35}$$

x_i	the ith station weight
x_{sum}	the total weight of all stations
$weight_i$	the influence of the station on the gridded value

The weight for each station was as follows:

Station 1:	0.6377
Station 2:	0.2587
Station 3:	0.1036

Using the results of the CROPSIM simulations for each weather station, the water balance parameters for an irrigated corn crop grown in a 831 soil in 1985 were compiled into Tables 9 – 11. Additionally, the evapotranspiration was gathered for the dryland crop on an 831 soil in 1985 (Tables 12 – 14). The dryland ET was used as an estimate for a rainfed crop.

Table 9. Water balance for irrigated corn on a 831 soil – 1985 Wayne, NE (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation	0.19	0.09	1.40	6.99	3.11	4.20	1.04	3.99	3.87	0.69	0.40	0.11	26.08
Net Irrigation Requirement	-	-	-	-	-	-	3.40	2.14	0.85	-	-	-	6.39
Evapotranspiration	0.22	0.50	1.01	1.95	2.65	3.67	7.51	5.31	3.46	1.74	0.09	0.18	28.29
Deep Percolation	-	-	0.02	1.63	0.38	-	-	-	-	-	-	-	2.03
Runoff	-	-	-	3.52	0.54	1.21	-	0.52	0.15	-	-	-	5.94

Table 10. Water balance for irrigated corn on a 831 soil – 1985 Walthill, NE (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation	0.25	0.10	2.12	5.69	3.18	1.56	1.13	4.23	4.67	1.61	0.91	0.62	26.07
Net Irrigation Requirement	-	-	-	-	-	-	6.39	1.26	0.85	-	-	-	8.5
Evapotranspiration	0.24	0.48	1.02	2.16	2.62	4.62	7.83	5.59	2.78	0.89	0.45	0.19	28.87
Deep Percolation	0.09	-	0.24	1.98	0.33	-	-	-	-	-	-	-	2.64
Runoff	-	-	0.12	2.05	0.83	0.01	0.08	0.34	0.20	0.03	-	-	3.66

Table 11. Water balance for irrigated corn on a 831 soil – 1985 West Point, NE (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation	0.30	0.14	2.46	4.53	3.69	2.28	1.19	3.51	5.53	1.03	1.16	0.41	26.23
Net Irrigation Requirement	-	-	-	-	-	-	5.10	1.70	0.85	-	-	-	7.65
Evapotranspiration	0.22	0.38	1.02	2.14	2.58	4.94	7.34	5.06	2.76	0.86	0.43	0.18	27.91
Deep Percolation	0.16	-	0.40	1.21	0.52	-	-	-	-	-	-	-	2.29
Runoff	-	-	0.35	1.87	0.73	0.07	0.03	0.60	0.77	-	-	-	4.42

Table 12. Evapotranspiration for dryland corn on a 831 soil – 1985 Wayne, NE (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Evapotranspiration	0.27	0.64	1.10	1.73	2.63	3.68	6.14	3.20	2.92	1.72	0.12	0.23	24.38

Table 13. Evapotranspiration for dryland corn on a 831 soil – 1985 Walthill, NE (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Evapotranspiration	0.31	0.60	1.16	2.25	2.60	4.63	5.06	3.59	2.45	1.31	0.37	0.26	24.59

Table 14. Evapotranspiration for dryland corn on a 831 soil – 1985 West Point, NE (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Evapotranspiration	0.31	0.61	1.21	2.22	2.59	4.95	4.86	3.16	2.48	1.31	0.33	0.25	24.28

These values are weighted appropriately to yield the following gridded water balance parameters for cell 23,546 (Tables 15-16).

Table 15. Water balance for irrigated corn on a 831 soil – 1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation	0.22	0.10	1.70	6.40	3.19	3.32	1.08	4.00	4.25	0.96	0.61	0.27	26.10
Net Irrigation Requirement	-	-	-	-	-	-	4.35	1.87	0.85	-	-	-	7.07
Evapotranspiration	0.23	0.48	1.01	2.02	2.63	4.05	7.58	5.36	3.21	1.43	0.22	0.18	28.40
Deep Percolation	0.04	-	0.12	1.68	0.38	-	-	-	-	-	-	-	2.22
Runoff	-	-	0.07	2.97	0.63	0.78	0.02	0.48	0.23	0.01	-	-	5.19

Table 16. Evapotranspiration for dryland corn on a 831 soil –1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Evapotranspiration	0.28	0.63	1.13	1.92	2.62	4.06	5.73	3.30	2.75	1.57	0.21	0.24	24.44

The following calculations take place in the Irrigation Application and Demand program (IAD).

The IAD determines the volume of water applied to the crops. The first step is to determine the depth of gross pumping applied. The NIR is multiplied by the target adjustment then divided by the application efficiency (Equation 36; Table 17).

$$GWP_j = NIR_j * \frac{ADJ_{NIR}}{AE_{GW}} \tag{36}$$

GWP_j	Depth of pumping for crop j (in) – (Table 17)
NIR_j	Net irrigation requirement for crop j (in) – (Table 15)
ADJ_{NIR}	NIR adjustment factor – (Coefficient File)
AE_{GW}	Application efficiency for groundwater pumping – (Application Efficiency File)

Table 17. Depth of pumping on irrigated corn on a 831 soil –1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pumping	-	-	-	-	-	-	4.62	1.99	0.90	-	-	-	7.51

These depths are then translated to a cell total pumping volume by multiplying the crop depth by the number of crop specific acres (Equation 37; Table 18)

$$GWP_{cell} = \sum \frac{GWP_j * Ac_j}{12} \tag{37}$$

GWP_{cell}	Total volume of pumping for the cell (AF) – (Table 18)
GWP_j	Depth of pumping for crop j (in) – (Table 17)
Ac_j	Acres of groundwater only crop j grown in the cell (acres)

Table 18. Volume of groundwater pumping on a 831 soil –1985 cell 23,546 (AF)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pumping	-	-	-	-	-	-	61.63	26.49	12.04	-	-	-	100.16

The following calculations are used to estimate the field water balance parameters within the WSPP program.

The process begins with the gridded water balance parameters for the irrigated crop (Table 15) and dryland evapotranspiration (Table 16). Adjustments are made to the gridded runoff and deep percolation. Any adjustment here is transferred directly to non-beneficial consumptive use (Equations 38-40). Since ADJ_{DP} and ADJ_{RO} are both equal to 1.00 (Coefficient File) there is no transfer.

$$RO_1 = RO * ADJ_{RO} \tag{38}$$

RO_1	Adjusted runoff (in)
RO	Runoff from gridded water balance parameters (in) – (Table 15)
ADJ_{RO}	Runoff adjustment factor – (Coefficient File)

$$DP_1 = DP * ADJ_{DP} \tag{39}$$

DP1	Adjusted deep percolation (in)
DP	Deep percolation from gridded water balance parameters (in) – (Table 15)
ADJ_{DP}	Deep percolation adjustment factor – (Coefficient File)

$$ET_{trans} = (DP - DP_1) + (RO - RO_1) \tag{40}$$

ET_{trans}	Runoff and deep percolation from the gridded water balance parameters converted into non-beneficial ET
DP1	Adjusted deep percolation (in)
DP	Deep percolation from gridded water balance parameters (in) – (Table 15)
RO_1	Adjusted runoff (in)
RO	Runoff from gridded water balance parameters (in) – (Table 15)

Next a consideration for the change in soil water content is made. No changes are made to precipitation, and no additional modifications are made to alter runoff or deep percolation after those shown in Equations 38–40. Therefore, to maintain the change in soil water content, all the results of the water balance partitioning must maintain Equation 41. The NIRmET values are shown in Table 19.

$$NIR - ET = NIRmET \tag{41}$$

NIR	Net Irrigation Requirement (in) – (Table 15)
ET	Evapotranspiration (in) – (Table 15)
NIRmET[13]	Initial soil water content consideration (in) – (Table 19)

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[13] NIRmET is not the soil water content it is used to maintain the change in soil water content.

Table 19. Change in soil water content consideration irrigated corn –1985 cell 23,546

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
NIR minus ET	(0.23)	(0.48)	(1.01)	(2.02)	(2.63)	(4.05)	(3.23)	(3.49)	(2.36)	(1.43)	(0.22)	(0.18)	(21.33)

A partitioning value is determined based upon the runoff and deep percolation gridded water balance parameters (Equation 42). The partitioning variable is used to split the ET adjustment and irrigation inefficiencies between runoff and recharge. The results of the partition variable can be seen in Table 20.

$$RODP_{wt} = \begin{cases} Min\left(Max\left(\frac{RO*RO_f DP}{RO*RO_f DP+DP}, RO_{\min}\right), RO_{max}\right) & RO+DP>0 \\ DryET2RO & RO+DP \leq 0 \end{cases} \tag{42}$$

$RODP_{wt}$	Irrigated partitioning factor – (Table 20)
RO	Runoff from gridded water balance parameters (in) – (Table 15)
RO_fDP	Weighting factor used to influence the effect of runoff on the irrigated partitioning factor – (Coefficient File)
DP	Deep percolation from gridded water balance parameters (in) – (Table 15)
RO_{min}	Lower limit to the irrigated partitioning factor – (hard coded to 0.05)
RO_{max}	Upper limit to the irrigated partitioning factor – (hard coded to 0.95)
DryET2RO	Dryland partitioning factor – (Coefficient File)

Table 20. Irrigated partitioning factor on irrigated corn –1985 cell 23,546

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigated Partitioning Factor	0.05	0.40	0.37	0.64	0.62	0.95	0.95	0.95	0.95	0.95	0.40	0.40

ET gain is the increase in ET from the beneficial application of irrigation water. There is a pattern of diminishing returns for ET on the volume of irrigation water applied over the growing season. For this reason, calculations on ET are based upon irrigation season totals. The irrigation season is defined as the months where NIR is greater than 0. The seasonal Variables needed to calculate ET gain are applied irrigation, irrigated ET, and dryland ET. The seasonal totals for these variables are shown in Table 21.

Table 21. Irrigation season pumping and ET on irrigated corn –1985 cell 23,546

Parameter	Seasonal Total
Applied Irrigation	7.51
Irrigated ET - Irrigation Season	16.15
Dryland ET - Irrigation Season	11.78

Determining the ET gain as a result of applied irrigation is the next step. Using a diminishing returns function the ET gain is calculated from the applied irrigation, the consumptive irrigation requirement, and the gross irrigation requirement (Equation 43 - 46). The results are shown in Table 22.

$$ET_{gain} = \begin{cases} \mathrm{Max}\left(\mathrm{Min}\left(CIR\left(1-\left(1-\frac{\mathrm{Irr}_{\mathrm{app,sea}}}{GIR}\right)^{\frac{1}{\beta}}\right), \mathrm{Irr}_{\mathrm{app,sea}}\right), 0.\right) & \mathrm{Irr}_{\mathrm{app,sea}} < GIR \\ ET_{irr,sea} - ET_{dry,sea} & \mathrm{Irr}_{\mathrm{app,sea}} > GIR \end{cases} \tag{43}$$

ET_{gain}	Increase in evapotranspiration from the application of irrigation water (in) – (Table 22)
CIR	Consumptive irrigation requirement, the depth of additional irrigation water needed to be consumed by the crop to reach full ET (in) (Equation 44) – (Table 22)

$$CIR = Max\left(ET_{irr,sea} - ET_{dry,sea},\ 0.00001\right) \tag{44}$$

$Irr_{app,\ sea}$	Depth of irrigation water applied during the irrigation season (in) – (Table 21)
GIR	Gross irrigation requirement, the depth of total irrigation water needed to be applied, given the efficiency of the system, to deliver enough water to the soil profile to meet full ET (in) (Equation 45) – (Table 22)

$$GIR = \frac{NIR_{ann}}{AE_{GW}} \tag{45}$$

β	Water use efficiency (Equation 46) – (Table 22)

$$\beta = \frac{CIR}{GIR} \tag{46}$$

$ET_{irr,\ sea}$	Irrigated ET during the growing season (in) – (Table 21)
$ET_{dry,\ sea}$	Dryland ET during the growing season (in) – (Table 21)

Table 22. Components for ET gain on irrigated corn – 1985 cell 23,546 (in)

Parameter	Value
Consumptive Irrigation Requirement	4.37
Gross Irrigation Requirement	8.84
Water Use Efficiency (β)[14]	0.49
ET gain	4.28

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[14] The water use efficiency in this example is lower than expected. This is caused by timely precipitation events and the fact that the soil water balance model does not use a forecasting function. This allows model to trigger an irrigation event, followed by a precipitation event in the immediate future. The precipitation was enough to provide sufficient soil moisture for transpiration purposes, limiting the effectiveness of the irrigation event.

The ET gain then needs to be distributed back to the months. This is done using three sets of monthly criteria. If there is any ET gain remaining after one set of criteria, the remainder is subject to the next criterion. All of the calculations for cell 23,546 in 1985 fall under the first criteria.

1) The monthly applied irrigation is greater than 0 and irrigated ET (ET_{irr}) is greater than the dryland ET (ET_{dry}). The ET gain is then distributed weighted by the relative difference between the ET_{irr} and ET_{dry}. The total ET gain within a month is limited to the depth of water applied to the crop (ET gain <= Applied Irrigation Water).

2) Applied water greater than 0 and ET_{dry} greater than ET_{irr}. The ET gain is then distributed weighted by the relative depth of applied water. The total ET gain within a month is limited to the depth of the water applied to the crop (ET gain < applied water).

3) Applied water was 0 and ET_{irr} was greater than ET_{dry}. The ET gain is distributed weighted by the relative ET_{irr}.

Using the rules defined above, all of the ET gain for cell 23,546 in 1985 will be experienced from July to September. The ET difference in these months was summed and the ET gain is weighted based upon the ET difference in a given month divided by the sum of the differences in each month. The results are shown in Table 23.

Table 23. Distribution of ET gain to the months on irrigated corn – 1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ET gain	-	-	-	-	-	-	1.81	1.99	0.46	-	-	-	4.25

The ET base component, from either the dryland or irrigated ET, represents the ET which is expected when no irrigation is applied. The ET base is defined by Equation 47. The total ET is then found by summing the ET base with the ET gain. Table 24 shows the results.

$$ET_{base,n} = \begin{cases} ET_{irr,n} & Irr_{app,n} \leq 0 \\ ET_{dry,n} & Irr_{app,n} > 0 \quad ET_{irr,n} > ET_{dry,n} \\ ET_{irr,n} & Irr_{app,n} > 0 \quad ET_{irr,n} < ET_{dry,n} \end{cases} \tag{47}$$

$ET_{base, n}$	The non-irrigated level of ET for an irrigated crop (in) – (Table 24)
$ET_{irr, n}$	Irrigated ET (in) – (Table 15)
$ET_{dry, n}$	Dryland ET (in) – (Table 16)
$Irr_{app, n}$	Applied Irrigation (in) – (Table 17)
n	month index

Table 24. Non-irrigated component of ET and total ET on irrigated corn – 1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ET base	0.23	0.48	1.01	2.02	2.63	4.05	5.76	3.30	2.75	1.43	0.22	0.18	24.06
ET[15]	0.23	0.48	1.01	2.02	2.63	4.05	7.57	5.29	3.21	1.43	0.22	0.18	28.31

The full ET in Table 24 represents an idealized amount under the assumption that water is the only limiting factor in production, or strictly moving down the production curve. The exogenous forces that are not simulated in the soil water balance model are now implemented using the ET adjustment factor (Equation 48). The adjusted ET is shown in Table 25.

$$ET_{irr,adj} = ET * ADJ_{ET,irr} \tag{48}$$

$ET_{irr, adj}$ Adjusted Irrigated ET (in) – (Table 25)
ET ET under only water limited conditions (in) – (Table 24)
$ADJ_{ET, irr}$ Irrigated ET adjustment factor – (Coefficient File)

Table 25. Adjusted Irrigated ET on irrigated corn – 1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Adjusted ET	0.22	0.45	0.95	1.89	2.46	3.79	7.09	4.95	3.00	1.34	0.21	0.17	26.53

While applying irrigation water, a portion of the water is lost to various non-beneficial uses (drift, evaporation, interception, etc…). Therefore a surface loss is calculated as a fixed percentage of applied water (Equation 49; Table 26).

$$SL = Irr_{app} * Fsl_{gw} \tag{49}$$

SL Evaporative surface losses (in) – (Table 26)
Irr_{app} Applied Irrigation (in) – (Table 17)
Fsl_{gw} Surface loss fraction for groundwater – (Coefficient File)

Table 26. Groundwater surface losses on irrigated corn – 1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Surface Loss	-	-	-	-	-	-	0.09	0.04	0.02	-	-	-	0.15

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[15] This is the rate of ET given the depth of applied irrigation.

The next step is to determine if there is any unaccounted for water after applying irrigation, crop water uses, surface losses and considerations for change in soil water (Equation 50). Any excess water is divided between runoff and deep percolation using the partitioning variable (Equations 51–52)[16]. The results are shown in Table 27.

$$Ewat = Irr_{app} - SL - ET_{irr,adj} - NIRmET \quad (50)$$

$$RO_2 = MAX(Ewat * RODP_{wt}, -RO_1) \quad (51)$$

$$DP_2 = MAX(Ewat * (1 - RODP_{wt}), -DP_1) \quad (52)$$

Ewat	Undefined water after considering applied irrigation, evapotranspiration, irrigation surface losses, and changes in soil water (in) – (Table 27)
Irr_{app}	Applied Irrigation (in) – (Table 17)
SL	Evaporative surface losses (in) – (Table 26)
$ET_{irr, adj}$	Adjusted Irrigated ET (in) – (Table 25)
NIRmET[13]	Initial soil water content consideration (in) – (Table 19)
RO_2	Additional runoff from irrigation inefficiencies and ET adjustment for non-idealized conditions (in) – (Table 27)
DP_2	Additional deep percolation from irrigation inefficiencies and ET adjustment for non-idealized conditions (in) – (Table 27)
$RODP_{wt}$	Irrigated partitioning factor – (Table 20)
RO_1	Adjusted runoff (in)
DP_1	Adjusted deep percolation (in)

Table 27. Partitioned irrigation inefficiencies and ET adjustments for non-idealized conditions on irrigated corn – 1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Excess Water	0.01	0.03	0.06	0.13	0.17	0.26	0.67	0.48	0.24	0.09	0.01	0.01	2.17
Runoff	0.00	0.01	0.02	0.08	0.10	0.24	0.64	0.46	0.23	0.09	0.01	0.00	1.88
Deep Percolation	0.01	0.02	0.04	0.05	0.06	0.01	0.03	0.02	0.01	0.00	0.01	0.01	0.28

The total annual deep percolation is tabulated (Equations 53).

$$DP_{tot} = \sum DP_1 + \sum DP_2 \quad (53)$$

DPtot	Total depth of deep percolation (in) – (Table 28)
DP_1	Adjusted deep percolation (in)
DP_2	Additional deep percolation from irrigation inefficiencies and ET adjustment for non-idealized conditions (in) – (Table 27)

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[16] RO_2 and DP_2 are allowed to go negative but only to the point where they offset any adjusted runoff or recharge coming out of the soil water balance model.

Table 28. Total annual deep percolation on irrigated corn – 1985 cell 23,546 (in)

Parameter	Value
Total Deep Percolation	2.50

In the event that the total deep percolation exceeds the lower threshold defined in the coefficient file, the model begins to convert recharge to runoff. As deep percolation rates go to infinity the modeled deep percolation rates continue to a maximum limit defined in the coefficient file (Equation 54).

$$DP_{tot} = DP_{ll} + \left(DP_{cap} - DP_{ll}\right) * \left(1 - \left(1 - \frac{(DP_1 + DP_2) - DP_{ll}}{DP_{ul} - DP_{ll}}\right)^{\frac{1}{\alpha}}\right) \tag{54}$$

DP_{tot}	Realized rate of deep percolation (in)
DP_{ll}	Lower threshold for deep percolation tapering (in) – (Coefficient File)
DP_{cap}	Maximum annual specified deep percolation rate (in) – (Coefficient File)
DP_1	Adjusted deep percolation (in)
DP_2	Additional deep percolation from irrigation inefficiencies and ET adjustment for non-idealized conditions (in) – (Table 27)
α	function shape factor (Equation 55)

$$\alpha = \frac{DP_{cap} - DP_{ll}}{DP_{ul} - DP_{ll}} \tag{55}$$

DP_{lu}	This is upper limit used to simulate infinity. For the LPMT model it is defined as DP_{ll} + 100

As the annual modeled deep percolation rate did not exceed the minimum threshold on irrigated corn in 1995 within cell 23,546; no additional adjustment to the deep percolation was made. Had one been made the difference between the modeled rate and the realized modeled rate of deep percolation would have been converted into runoff. Both the realized deep percolation and the converted runoff would be divided among the month proportional to the depth of model deep percolation (DP_1 + DP_2).

The final total deep percolation and runoff values are compiled (Table 29) and scaled to the cell (Table 30).

Table 29. Total runoff and deep percolation on irrigated corn – 1985 cell 23,546 (in)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Runoff Totals	0.00	0.01	0.09	3.05	0.73	1.02	0.66	0.94	0.46	0.10	0.01	0.00	7.07
Deep Percolation Totals	0.06	0.02	0.14	1.74	0.43	0.01	0.03	0.02	0.01	0.00	0.01	0.01	2.49

Table 30. Total runoff and deep percolation on irrigated corn – 1985 cell 23,546 (AF)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Runoff Totals	0.01	0.16	1.25	40.68	9.78	13.63	8.76	12.52	6.12	1.27	0.07	0.06	94.32
Deep Percolation Totals	0.83	0.21	1.92	23.21	5.79	0.15	0.41	0.29	0.14	0.05	0.10	0.08	33.18

The following calculations take place in the Make Recharge program.

The runoff developed in the WSPP program is partitioned between indirect recharge, indirect evapotranspiration, and runoff contributions to stream flow. The first step is to calculate the loss factor. The loss factor is a function of the distance between the cell centroid and the stream gauge, and the loss per mile calibration parameter (Equation 56).

$$LossFactor = \begin{cases} 0.5 & Mi2Gauge = 0 \\ Min\left(1 - e^{-lpm*Mi2Gauge}, 1.0\right) & Mi2Gauge > 0 \end{cases} \tag{56}$$

LossFactor	Portion of runoff lost in transit between field and stream gauge – (Table 31)
Mi2Gauge	Distance between field and stream gauge (mi) – (Cell Location File)
Lpm	Rate at which transmission losses occur (%/mi) – (Runoff Zone Coefficient File)

Table 31. Loss Factor – cell 23,546 (AF)

Parameter	Value
Loss Factor	0.14

The loss factor is used to partition the runoff between the transmission losses and contribution to stream flow (Equation 57). The transmission losses are further partitioned into indirect recharge and indirect evapotranspiration (Equations 58–28). The complete runoff balance for cell 23,546 is shown in Table 32.

$$SF = RO * (1 - LossFactor) \tag{57}$$

$$RO2DP = RO * LossFactor * \%2Rch \tag{58}$$

$$RO2ET = RO * LossFactor * (1 - \%2Rch) \tag{59}$$

SF	Runoff contributions to stream flow (AF) – (Table 31)
RO2DP	Runoff transmission losses to recharge (AF) – (Table 31)
RO2ET	Runoff transmission losses to evapotranspiration (AF) – (Table 31)
LossFactor	Portion of runoff lost in transit between field and stream gauge – (Table 31)
%2RCH	Partitioning factor splitting the transmission losses between recharge and ET – (Coefficient File)

Table 32. Runoff balance for irrigated corn – 1985 cell 23,546 (AF)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Total Runoff	0.01	0.16	1.25	40.68	9.78	13.63	8.76	12.52	6.12	1.27	0.07	0.06	94.32
Runoff Contributions to Streamflow	0.01	0.14	1.07	34.99	8.41	11.73	7.53	10.77	5.26	1.10	0.06	0.05	81.13
Indirect Recharge	0.00	0.01	0.11	3.70	0.89	1.24	0.80	1.14	0.56	0.12	0.01	0.01	8.57
Indirect Evapotranspiration	0.00	0.01	0.06	1.99	0.48	0.67	0.43	0.61	0.30	0.06	0.00	0.00	4.62

There was no canal or miscellaneous recharge within this cell. Therefore the direct recharge from the field and the indirect recharge were combined together, converted to the appropriate units (feet/day), and put into the properly formatted .RCH file.

The following calculations are made in the Make Well Program

Cell 23,546 did not contain any municipal and industrial or miscellaneous pumping. Well within the cell were classified as withdrawing water solely from the principal aquifer. Finally the cell was not a river cell. The pumped volume (Table 18) was converted into the appropriate units (ft^3/day) and inserted into a properly formatted .WEL file.

Conversion technique for converting between Cell ID and Row-Column

This method is based upon a grid that starts in the upper left-hand corner and proceeds like a type writer left to right for each row. Equations 60-65 show the conversion method.

$$cell = (row - 1) * ncols + col \tag{60}$$

Cell	The cell ID
Row	The row the cell resides within
Col	The column the cell resides within
Ncols	The total number of columns in the grid (282)

$$col = \begin{cases} MOD(cell, ncols) & MOD(cell, ncols) <> 0 \\ ncols & MOD(cell, ncols) = 0 \end{cases} \tag{61}$$

$$row = \frac{cell - col}{ncols} + 1 \tag{62}$$

Example cell 23,546

$$cell = (84 - 1) * 282 + 140 = 23546 \tag{63}$$

$$col = MOD(23546, 282) = 140 \tag{64}$$

$$row = \frac{23546 - 140}{282} + 1 = 84 \tag{65}$$